A STATISTICAL ANALYSIS OF WET LOADING MODELS FOR THE ADIRONDACK PARK

By

MARK LINCOLN SPRINGER

Bachelor of Science in Chemical Engineering

University of Arkansas

Fayetteville, Arkansas

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Thesis Adviser

Dean of the Graduate College

PREFACE

A model for estimating the ionic composition (quality) of rainfall in the Adirondack Park using a Guassian plume model was developed. This model was combined with a quantity model based on loading. The quality model was evaluated using the statistical quality control methods outlined by Demming. The model was then compared to a previously developed model based on the Arithmetic method. Although this model constitutes a second estimate, it does not differ significantly from the Arithmetic method which was used as a first estimate.

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A - area (km^2 or mi^2)

A_i - area represented by rainfall station $_i$ (mi^2 or km^2)

AE - areal error (cm)

b -Bessel function parameter

BMA/BMN - Big Moose monitoring site

C - ion concentration (mg/m^3)

CA^{++} - calcium ion

CAN - Canada Lake monitoring site

C_1 - the concentration of ion 1 l(mg/l)

C_i - event ion concentration (μeq/l)

CLE - Clear Lake monitoring site

DEP - loading (μeq/l or eq/HA)

E - actual elevation (ft.)

E - expectation used in E(Qi-Q)

E - sampling error (in^2)

E - variance of the observed error (in cm)

ϵ - the fraction of aerosol collected by cloud droplets (dimensionless)

$F_1(I)$ - time parameter (dimensionless) (see fig. 2)

$F_2(N)$ -- gaging parameter (dimensionless) (see fig. 3)

G - gaging ratio ($gages/mi^2$)

G - storm gradient or spatial gradient index

GPR - gaging ratio (number of $gages/mi^2$)

λ_{io} - the semivariance between the ith station and the point of interest (in^2 or cm^2)

λ_i - variogram at ion 1 [$(\mu eq/l)^2$ or $(mg/l)^2$]

H - height of the cloud base (km)

H^+ - hydrogen ion

h - distance between rainfall stations (km or mi)

K - empirical altitude constant (in/ft)

k - isohyetal constant (dimensionless)

k_{ii} - eddy diffusivity (cm^2/s)

L - liquid water content of the cloud (g/m^3)

Λ - washout coefficient (s^{-1})

λ - weighing factor for kreiging (dimensionless)

MSE - mean square error

MSE_ϵ - observed mean square error

m - maximum recorded precipitation (in)

μ - lagrange multiplier (in^2 or cm^2)

ME - error in measurement (cm)

N - degree of discretization (same as gaging ratio)

N(h) - number of pairs of data with separation h

NH_4^+ - ammonium ion

NO_3^- - nitrate ion

P - region mean of the precipitation (in.)

P_i - weighing factor (dimensionless)

Pi - event amount precipitation (cm)

pm - average rainfall (in.)

PAS - Paul A. Smith monitoring site

Q - quantity of rainfall over the area in question (in or cm)

Q' - the average rainfall at a higher point (in)

Q - source strength ($\mu eq/m^3$)

Q_i - quantity of rainfall at point i (in or cm)

Q - average rainfall (in or cm)

R_i - rainfall recorded at station i (in or cm)

R_1 - rate of accumulation or disappearance of ion 1 (μeq/ls)

R - precipitation rate (cm/s)

r - distance from x and a randomly chosen point in the area of interest (mi)

σ_w - density of rain (g/ml)

S - variance (in or cm)

S_1 - emission rate of ion 1 (μeq/s)

$SO_4^=$ - sulfate ion

σp^2 - grand standard deviation (in^2 or cm^2)

σ_ϵ - variance of the observed errors

$\sigma_{y,}z$ - diffusion/disposition parameters (m)

t - time (s or hr)

tiE - the errors (cm)

u - wind speed (m/s)

u_j - wind velocity at point j (m/s)

W - washout rate

y - distance from the x axis (m)

X - average rainfall (in or cm)

x - distance km

x_i - the x coordinate of the point of interest

CHAPTER I

INTRODUCTION

The Adirondack Park area of New York has been the object of several studies because of the dramatic effects of acid deposition. There are presently three deposition monitoring sites in the park. A MAP3S/RAINE (Multi-State Atmospheric Power Production Pollution Study) site at Whiteface Mountain, a Utility Acid Precipitation Study Program (UAPSP) site at Big Moose and a National Atmospheric Deposition Program (NADP) site at the Huntington wildlife station. A fourth site at Ithaca, New York is operated by MAP3S/RAINE, while not in the park itself, it is in close proximity to the park.

In 1978, a study of three lake watersheds in the central Adirondack mountains region of New York state was conducted under the auspices of the Electric Power Research Institute (EPRI) by Rensselaer Polytechnic Institute. This study, the integrated lake watershed acidification study (ILWAS) included the sampling of both wetfall and dryfall at seven sites near the three lakes. These three lakes are located in a central location within the park and are all within a 15 kilometer radius of the Big Moose field laboratory near Big Moose, New York.(1,2,3,4).

Of the results obtained, the most important for this work was the confirmation of the first two hypotheses which guided the Rensselaer researchers work (4):

1. Over a limited area of interest (675 km^2), the precipitation quality received by the three watersheds were identical within the limits of measurement.

2. Over the same area, the quantity of precipitation was likewise constant.

ILWAS was superseded by the Regional Integrated Lake-Watershed Study (RILWAS) in June 1982. RILWAS was conducted for two years until June 1984. This study expanded the data collection network to sites representing 20 watersheds in the park. The next study is expected to include 200 watersheds.

The RILWAS study challenged the ability of researchers to collect data to its practical limit. Such factors as siting (no more than 1 km from an all-weather road), manpower, and permission of landowners, makes it highly unlikely that the next study will be able to increase the number of precipitation collectors in the network. Therefore, it is necessary to develop a working model to pinpoint potentially vulnerable areas so that sampling sites may be located there.

Acid deposition includes both wetfall and dryfall; however, this model deals only with wetfall. The ILWAS study addressed whether dryfall could be accurately quantified by the sampling procedures used. Unfortunately, the ILWAS team discontinued dryfall collection at all but one site after nine months. A major study on dryfall sampling techniques will be required before a model for dryfall can be developed.

Acid deposition is a mesoscale phenomenon, and by its very nature is difficult to quantify. Such processes as advective and diffusive transport, vertical mixing, scavenging, gaseous and aqueous-phase mass transfer, vertical convective removal and wet/dry deposition are not yet fully understood.(5)

As a result of the RILWAS study Rogowski (6) developed the ROGO model, a wet loading model for the Adirondack park. This model consists of two parts, a quantity model and a quality model which are then combined to form a wet loading model. These models form the basis of the Oklahoma State-Acid Wet Deposition Model (OSAWD) and will be discussed in detail in the chapter on the OSAWD model.

The objectives of this thesis are to:

1. Develop a model for predicting the ionic concentrations (also called rainfall quality) of rainfall at any given location in the park.

2. Develop a criterion for judging the accuracy of this model or any other model.

CHAPTER II

LITERATURE REVIEW

By definition, wet loading is the quantity of precipitation multiplied by the quality of the precipitation.

Loading = (Quantity of wetfall x Quality of wetfall)

where quality of wetfall is defined as the composition of the wetfall. Because there does not appear to be any relationship between the quantity and quality of the wetfall, i.e., the atmospheric ion concentrations do not appear to effect the rainfall frequency or quantity, a loading model could consist of two distinct models; a quality model and a quantity model.

Quantity Models

Precipitation quantity estimates have been of interest to civil engineers and farmers for centuries. The earliest method for estimating the quantity of rainfall over an area of interest was the Arithmetic Method. The Arithmetic Method relied on a simple arithmetic average of the rainfall measured at each of the stations located in the area of interest. This simple method works well when the rain gages are uniformly spaced over level terrains. In 1911 Theissen (7) developed a method for estimating rainfall over areas where rain gage stations were irregularly spaced.

$$Q = \Sigma A_i R_i / \Sigma A_i \tag{2}$$

where Q = the quantity of rainfall over the area in question (in. or cm)

A_i = area represented by the rainfall station i (mi^2 or km^2)

R_i = rainfall recorded at station i (in. or cm)

As with the arithmetic method, this method works well when rain gages are placed over level terrain. Linsley (8) proved that the results obtained by dual linear interpolation are essentially the same as the Theissen Method. This method will be referred to as the Linsley/Theissen method, and is the most common method used in the world today to predict rainfall.

Finklestein (9) recommends using Kriging to estimate areal rainfall depth. Kriging is a weighted average or interpolative method where

$$Q = \Sigma \lambda_i R_i \tag{3}$$

where λ_i = a weighting factor which is found when the variance in the estimation of the rainfall at the point in question is at a minimum (dimensionless)

$$\text{Var}\,(\Sigma Q_i - \overline{Q}) = \Sigma \lambda_i \gamma_{io} + \mu \tag{4}$$

where μ = a Lagrange multiplier (in^2 or cm^2)

γ_{io} = the semivariances between the ith station and the point of interest (in^2 or cm^2)

Q_i = the quantity of rainfall at point i (in or cm)

$\overline{Q}$ = the average rainfall over the area of interest (in or cm)

$$\gamma_{io} = \frac{1}{2N(h)} \cdot \Sigma \, [R(Rx_i + h) - R(x_i)]^2 \qquad (5)$$

where N(h) = is the number of pairs of data with the separation h

h = is the distance between points, (mi or km)

x_i = the coordinate in the x direction of station i

Kriging, may be applied in the x or y direction or in both directions simultaneously.

In the 1920's an alternative method of rainfall estimation based on the characteristics of the storm cell system known as isohyeting was proposed. This method requires an understanding of the basic types of storms found in the region of interest and proper identification of any given storm. Court (10) gives the area-depth equation for a one day storm over the entire United States as

$$Q = m\,(k - kA^{\frac{1}{2}} + k^2A/2 - k^3A^{3/2}/6 + \ldots) \qquad (6)$$

where m is the maximum recorded precipitation (in).

k is a constant between 0.00105 & 0.0189

A is the area of interest (mi^2).

Finklestein (9), Corbett (11), and Linsley (8) consider the isohyet method to be the most accurate; however, it must be noted that the results are not subject to reproduction as human judgment is a major factor in using this method. Unlike the Linsley/Theissen, Kriging and arithmetic methods, geographic effects can and are taken into effect. (This method is region specific, i.e., the equations are not usable from one region to another.)

Rainfall estimation is not solely a function of distance on the x-y plane. Donley & Mitchell (12) report that as early as the late

1890s Lippencott observed that rainfall was influenced by elevation and tended to follow a straight-line curve.

$$Q' = Q + K\ (E/100) \tag{7}$$

where Q' = the average annual rainfall at a higher point (in.)

Q = the average annual rainfall at a lower point (in.)

K = empirical altitude constant (in./ft.)

E = actual elevation (ft.)

Spreen (13) reported that in addition to the elevation, such factors as maximum slope of the, land, exposure and orientation of the stations to the inflow air masses were critical parameters involved in rainfall estimation. Spreen estimated that these factors plus elevation could account for 88 percent of the variance from values estimated using the isohyetal method. Of this, approximately 30 percent of the variance was due to elevation alone. Burns (14) in his study of topographic effects in the San Dimas experimental forest correlated rainfall with the elevation, slope, rise (the difference in elevation between the station and the highest elevation within a 5 miles radius of the station), the aspect, a term which describes the orientation of the ridgelines with respect to the storm tracks, and a zone of influence, which describes the geographic area of interest. Marlatt & Riehl (15) developed a weighting system which could be adapted to the Linsley/Theissen interpolative method, these weight factors, developed for the upper Colorado River basin varied from 0.165 for 6,360 ft. to 0.025 for 6,770 ft.

Errors

There are three types of errors which need to be quantified in the development of an area precipitation model:

(1) the discretization error

(2) sampling errors

(3) the errors in measurement

Bras & Rodriguez-Iturbe (16) have investigated and evaluated the mean square errors involved in approximating the areal average precipitation.

$$E(Q_i-\overline{Q})^2 = \frac{1}{N}2 \sum_{ij}\sum \operatorname{cov}(x_i,x_j) + \frac{1}{A}2\int\int \operatorname{cov}(x_1,x_2)dx_1dx_2 - \frac{2}{NA}\Sigma\int \operatorname{cov}(x,x_i)dx \tag{8}$$

where $E(Q_i\text{-}Q)^2$ = the mean square error (in,^{2})

N = the degree of discretization (number of sites/mi.$_2$)

x_i= the location of the point in space.

A = the area of interest (mi.^{2})

The equation is simplified by making the covariance a first order modified Bessel function of the second kind.

$$\operatorname{Cov}(r) = s^2 \text{ brk } (br) \tag{9}$$

where r = is the distance from x; and a randomly chosen point in area of interest (mi.)

S = the point variance (in.)

b = a parameter which is derived from the data.

A graphical solution to the problem has been developed where normalized mean square error is plotted as a function of the area Ab^2 and the degree of discretization. Lenton & Rodriguez-Iturbe (17) add a term to describe the accuracy of measurements.

$$MSE_\varepsilon = E(Q_i - \overline{Q})^2 + \sigma_\varepsilon^2 \Sigma P_i^2 \tag{10}$$

where MSE_ε = observed mean square error (in.^{2})

σ_{ε} = Variance of the observed errors (in.)

Rodriguez-Iturbe and Mejia (18) developed a graphical method to solve for the variance of the regional mean of the precipitation

$$Var[P] = \sigma p^2 \; (F_1(T) + F_2(N)) \qquad (11)$$

where Figures are used to solve for $F_1(T)$ and $F_2(N)$ and σp^2 is the grand standard deviation for point rainfall (in.^{2}).

McGuiness (19) used watersheds near Coshocton, OH to develop a nomograph to determine sampling error in event data. Huff (20) similarly developed a nomograph for event sampling errors and then developed equations for the sampling error for event, monthly, and seasonal precipitation based on the area of interest, number of gages per unit area, and the average rainfall. Silverman and Rogers (21) developed a sampling error based on a power function of gauging ratios and storm gradients.

$$S/X = 0.7105GPR + 0.5079G/GPR - 0.1381G/GPR^2 + 0.0121G/GPR^3 - 0.0531/GPR^2 \qquad (12)$$

where S/X = the expected error (dimensionless)

GPR = the gauging ratio (number of gages/mi.^{2})

G = spatial gradient index (dimensionless)

The third type of error is the error in measurement. Goodson (22) lists such factors as windspeed, air temperature, site exposure and gage configurations as the source of potential errors. Larson & Peck (23) observed that wind is the major cause of error in measurements and that errors are generally larger for solid than for liquid precipitation, likely due to site turbulence. Gage shields are often used to reduce site turbulence. Corbett (11) lists wind as well as evaporation, adhesion, color, inclination, splash and faulty technique in measuring the gage catch as other major causes of error. As cited by Corbett (11), Kurtyka estimates the approximate errors listed above (not including wind) at approximately -1.5% while the error due to wind at -5.0 to -80.0%. For wind speeds under 4 m/s, Goodson (22) noted that a Nipher shielded gage actually over-measures true snowfall. Using data from the Hydrologic Research Laboratory of the National Weather Service at Danville, VT, Larsen & Peck (23) have developed a graph of gage deficiencies vs. wind speed. Catch deficiencies as high as 70% for unshielded gages measuring snowfall in high winds (20 mph) were reported. Rainfall catch deficiencies of up to 20% in high winds were shown. Shielded gages collected about 20% more snow than unshielded, but 3 to 4% less rainfall Court (24) studied the precision of standard weighing rain gages and found that the reproducibility of such rain gages was $\pm$0.02 in.

Woodley et al. (25) showed that the errors in measurement are related to the gage catch with a minimum error of 5% for rainfalls of 25.4 mm increasing to 12% for rainfalls of 2.54 mm.

Rainfall Quality

The ionic composition of rainfall in a particular area may be considered a function of (1) the atmospheric concentration of the ion of interest, (2) the scavenging ratio, i.e., the ability of the rainfall to wash out the ions, and (3) boundary layer effects. The scavenging ratio may in turn be affected by the local meteorology.

The atmospheric concentration of ions may be modelled by two methods: (1) the Eulerian model based on the semi-empirical gradient transfer theory (sometimes called the K model), and (2) a Lagrangian model usually in the form of a Gaussian plume model. The Eulerian model begins with the continuity equation. The solution to this continuity equation gives concentration profiles of the various constituents. A typical model by Carmichael and Peters (26) is given below.

$$\partial C_1/\partial t + \mu_j \partial C_1/\partial x_k - \frac{\partial}{\partial x_i} (k_{jj}(\partial C1/\partial x_i) + R_1 + S_1 \qquad (13)$$

where C_1 is the concentration species 1 (mg/l)

t is time (s)

u_j is the wind velocity (m/s)

x_j is the x coordinate

k_{ii} is the eddy diffusivity (cm^2/s)

R_1 is rate of accumulation or disappearance of ion 1 (μeq/ls)

S_1 is the emission rate of ion 1 (μeq/s)

The rate of accumulation or disappearance of ion 1 (R_1), can be defined in terms of washout rate, reaction rate, and dry desposition rate. Lazaro (5) cites these advantages to an Eulerian model:

(1) The required input data are from fixed measured points.

(2) The model is capable of handling nonlinear atmospheric activity and physics.

(3) The model can be used to formulate the three dimensional wind field.

He also cites three major disadvantages:

(1) Large amounts of computer time are needed.

(2) Source-receptor relationships need to be generated.

(3) The pseudodiffusion error needs to be taken into account.

The Lagrangian model is based on a statistical distribution of pollutants. If the distribution used is a Markov process then the Lagrangian model reduces to the Eulerian model. If the distribution used is a normal distribution, the model reduces to a Gaussian plume model. The mathematics of the Gaussian plume model is discussed in detail in Chapter 3. Lazaro (5) lists the major advantages as:

(1) These models directly produce source-receptor relationships.

(2) They do not require large amounts of computer time.

(3) They allow mass volumes to be easily formulated.

Similarly, he lists the disadvantages as:

(1) Atmospheric processes must be highly parameterized.

(2) Non-linear processes are difficult to interpret.

(3) Interpolation error in converting from a Lagrangian to a Eulerian grid may be significant.

Gatz (27) defines the washout rate W as

$$W = \varepsilon\rho_w/L + \frac{H}{Rt}\,[1-\exp(-\Lambda t)] \tag{14}$$

where ε = the fraction of the aerosol collected by cloud droplets.

ρ_w = density of rain (g/ml).

L = Liquid water content of the cloud (g/m^3)

H = Height of the cloud bases (km).

R = Precipitation rate (cm/s).

t = rain duration (s).

Λ = washout coefficient (s^{-1}).

Bloxam, Hornbeck & Martin (28) have observed that the concentration of H^+, $SO_4^=$, NO_3^-, NH_4^+ and Ca^{++} yield higher concentrations in precipitation from convective storms rather than continous storms. They reported that geometric mean concentrations of $SO^{4=}$ in convective storms were 4.1 mg/l while in continuous storms they were 1.1 mg/l. They further report that both the surface and 850 millibar wind direction and the seasons have effects on the $SO_4{=}$ concentrations of rainfall. Using clusters and years of rainfall events, Moody, Swanson & Reynolds (29) have analyzed data from the UAPSP data base and have observed that $SO_4{=}$, NO_3^-, and H^+ concentrations and their respective ratios are related to the type of precipitation, either rain or snow.

Van Dop (30) has developed a method for incorporating topographic variances into mesoscale models. Using such parameters as the Obukhov stability parameter, friction velocity, boundary layer height and surface roughness, corrections may be made to a Gaussian plume model for such topographic influences as surface water, open fields, roads, forests, and buildings.

A method of estimating area desposition has been proposed by Granat (31). This method consists of calculating an estimated concentration field by mean interpolation between the network stations. Based on Hypothesis 1, Rogowski (6) used an arithmetic method to estimate ionic concentration. Finklestein (9) used the method of universal Kriging and has developed variograms for the H^+, $SO_4^=$, NO_3^- and NH_4^+ ions using the NADP and ILWAS data bases

$$\gamma_H = 4.51 + 0.233x = 0.000249x^2 - 7.36 -8x^3 \qquad (15)$$

$$\gamma_{SO4} = 0.048 + 0.00228x - 2.72E\text{-}6x^2 + 1.37E\text{-}9x^3 \qquad (16)$$

$$\gamma_{NO3} = 6.67E\text{-}4x \qquad (17)$$

$$\gamma_{NH4} = 7.81E\text{-}5x - 2.86E\text{-}8x^2 \qquad (18)$$

These variograms are based on annual average despositions, and are reliable to a distance of 2,400 km. The units of these variograms are in $(\mu eq/l)^2$ for the hydrogen ions and $(mg/l)^2$ for the other three ions. Finklestein observed that at distances of less than 30 km there was no detectable distance related variability. This is essentially the one observed by the ILWAS researchers (1). Granat (31) observed that all error in precipitation estimation under 20 km was random, i.e., there was no distance variability.

Quality Errors

Granat (31) investigated the random errors for precipitation events over an area of approximately 100 km in diameter. He developed curves of area variability vs. distance out to 300 km radius for the periods of events, months and years at distances greater than 100 km, the variability approached a constant value for any particular ion, ranging from about 15% for Ca^{++} amd Mg^{++} to about 3-4% for $SO_4^{=}$ and No_3^-. Although in his paper he only showed the curves for yearly variations, he stated that they were all similar except that the monthly time period would show greater standard deviations. He also developed tables of area variability for five areas of approximately 50 km diameter.

Depena, et al. (32) using 27 months of MAP3S data observed that weekly ion concentrations were lower than event concentrations for all ions analyzed. They reported differences ranging from 0.7% for Mg^+ to 5.7% for NO_3^-.

CHAPTER III

THE OSAWD MODEL

Quantity Model

Rogowski (6) chose a region bounded by the 45^{o} 00'N and 43^{o} 00'N latitude and 72^{o} 55'W and 75^{o} 35'W longitude as the field of operation for this model. This region includes the Adirondack park plus a border area and is divided into a 24 x 24 matrix, of which a 22 x 22 matrix is used for the model. Of the eight sites in the RILWAS network, four were chosen as quality monitoring sites. These four sites were selected for their strategic locations, and form the basis for the verification of the ROGO and OSAWD models. Two of the sites were chosen for locations near established monitors/networks. The Paul A. Smith College (PAS) site is located within 1 km of the Whiteface Mtn MAP3S site, the Big Moose (BMA) site was located at the ILWAS Big Moose monitoring site, 3 meters from the UAPSP #21 monitoring site. In September 1983, the Big Moose site was moved and given a new three letter designation, BMN. These sites, only 117 meters apart, are considered identical for the purposes of model identification. Two sites were chosen for their location in the park. Clear Lake (CLE) monitoring station is the easternmost RILWAS site. It is approximately 2.7 km directly south of Whiteface Mountain. The Canada Lake (CAN) station was added in March 1983 to investigate an observed trend of decreasing concentrations from the southwestern to northwestern regions of the park. Canada Lake is located in the extreme southeast corner of the park.

Precipitation amounts from 67 National Oceanographic and Atmospheric Administration (NOAA) sites within the 22 x 22 matrix are added to the matrix and the data in the missing matrix squares is estimated by a double linear interpolation (the Linsley/Theissen method). Rogowski reported that the errors in the calculation of matrix squares ranged from 7.9% to 17.0%. He also reported the actual RILWAS sites showed poorer agreement with the ROGO model with errors ranging from 19.0% to 89.0%. Rogowski speculated that the discrepancies in his model resulted from topographic effects which the ROGO model does not take into account. The Rogowski quantity model is the basis for the OSAWD quantity model.

Quality Model

The basis of the Rogowski quality model is an observation made from the extension of hypothesis number one of the ILWAS research: the quality of the wetfall does not change appreciably over the range of 30 km. This observation extends hypothesis one to state that the quality of rainfall at any site in the Adirondack park does not vary as much as the precipitation quantity, and as a first approximation can be taken as constant. This observation was proved to hold true by Garrity. (33) Rogowski also observed that the monthly concentration of ions at the Ithaca MAP3S site was always higher than the concentration of ions at the Whiteface Mountain MAP3S site. These two points were used as upper and lower bounds when determining concentrations. The Rogowski model used a single concentration for each ion at all the sites in the model region. These concentrations were the average of concentrations of the Ithaca and Whiteface Mountain MAP3S sites. The Rogowski model worked reasonably well. Garrity observed that the actual loadings for the major ions ($SO_4^=$, $NO_3^=$, H^+) at the BMA/BMN, CLE, and PAS sites either followed the average loading or fell between the average loadings and the Ithaca loadings. The CAN site added later showed a higher loading than the Ithaca loading. It was also observed that the data indicate a trend of slightly decreasing concentrations of all the ions from the southwestern to the northeastern regions of the park. Garrity finally suggested that a second approximation of wetfall quality be made using an inverse lever arm rule.

The OSAWD Model

The Oklahoma State Acid Wet Deposition model is a wet loading model based on Rogowski's wet loading model of the Adirondack Park. Like the ROGO model, the OSAWD model defines loading as the quantity of precipitation multiplied by the quality of the precipitation.

Loading was chosen as the means of describing deposition because Johannes (1) felt that loading more accurately reflected the effects of acid deposition for the site being considered. The alternative, a model based on monthly ion concentration, may show the effects of high ion concentrations but because of low wetfall amounts, the actual recorded effects may not be significant. Even though the model is not based on monthly weighted ion concentration, it incorporates them in the quality model. The OSAWD quality model defines monthly weighted ion concentration as the product of concentration and precipitation amount divided by total precipitation.

$$\text{Weighted Concentration} = \Sigma C_i P_i / \Sigma P_i \quad (19)$$

Where P_i = event amount of precipitation (cm)

C_i = event ion concentration (µeg/l)

The quality model is based on the normal distribution of the dispersion of a plume in the horizontal and vertical directions as suggested by D.B. Turner.(34)

$$C(x,yz;H) = Q/(2\Pi\sigma_y\sigma_z u)\exp[-\tfrac{1}{2}(y/\sigma_y)^2] + \tfrac{1}{2}\exp[-\tfrac{1}{2}(\frac{z-H}{\sigma_z})^2] \quad (20)$$

where: C = concentration, (µg/m^3)

Q = source strength, (µg/s)

u = wind speed, (m/s)

y = distance from the x-axis, (m)

σ_y, σ_z = coefficients which estimate dispersion, (standard deviations), (m)

This technique is the standard method for the estimation of concentration out to a distance of less than 100 km downwind.

The normal distribution model may be simplified by the following assumptions:

1. The source is at ground level.
2. The receptor is at ground level.
3. There is no reflection of pollutants upward.
4. σ_y and σ_z are calculated using a stability class "D".
5. There is a virtual source Q which is at some distance downwind from Ithaca, New York which is on a direct line with Ithaca and Whiteface Mountain, New York.
6. The source strength and windspeed may vary from month to month.
7. The virtual source distance from Ithaca, New York may vary from month to month.

The model then becomes:

$$C(x,0,0;0) = Q/\Pi\sigma_y\sigma_z u \qquad (21)$$

because the source has been defined to be on a line running from Ithaca, New York to Whiteface Mountain, New York, we can say for any given month:

$$Q/u = C_{ith}\sigma_{ith}\sigma_{zith}\Pi = C_{whi}\sigma_{whi}\sigma_{zwhi}\Pi \qquad (22)$$

Using this, and the distance from Ithaca, New York to Whiteface, New York we can solve for σ_{yITH} and σ_{zITH} from relationships given by Wark and Warner (35):

$$\sigma_y = 68x^{0.894} \qquad (23a)$$

and

$$\sigma_z = 44.5x^{0.516}-13 \qquad (23b)$$

where x = distance from the virtual source (km)

Any other points to be modeled may be done so with the relationship:

$$C(z,y,0;0) = \int C_{ith}\sigma_{yith}\sigma_{zith}/\sigma_y\sigma_z \div \exp[-\tfrac{1}{2}(y/\sigma_z)^2] \qquad (24)$$

This is the OSAWD Model.

The OSAWD Model presents several advantages over previous mesoscale dispersion models:

1. It is relatively simple.
2. It does not require a source input.
3. It does not require any knowledge of atmospheric dispersion coefficients or air turbulence.
4. It is based on sound theoretical reasoning.
5. The terms for vertical and horizontal diffusion (σy and σz) can be manipulated to improve the estimations.

6. It is based on observed ion concentrations.

Although Turner cautions his users about the accuracy of his estimates of σ_y and σ_z, beyond a few kilometers from the source, the OSAWD model does not assume that this is a problem since these parameters are forced to fit the ionic concentrations measured at the Ithaca and Whiteface Mountain MAP3S. This force fit also eliminates the need to know the details of the local weather. The stability class "D" is used to calculate σ_y and σ_z because class "D" is recommended by Turner for use during overcast conditions during either day or night regardless of wind speed. Since we know that during an event it will most likely be overcast and we cannot observe a wind speed, it follows that this assumption is reasonable.

Fisher (36) reports that the influence of source height is restricted to within 100 km of the source. This allowed for the simplification of the OSAWD model by the elimination of the stack height term in the general dispersion equation because the closest virtual source calculated for the model is approximately 300 km from the Ithaca sampling station. The location of the virtual source on a direct line from Ithaca, New York and Whiteface Mountain, New York lies on a direct line between the Ohio Valley and the receptors; the reason that the MAP3S sites were located there. It was also noted in the RILWAS observations that the concentration decreases from the southwest to the northeast. These observations allowed the simplified calculations, since the virtual source is imaginary, nothing is known about the windspeed and upwind precipitation, and scavenging mechanisms appear to change seasonally. The source strength, wind speed and the distance of the virtual source from Ithaca, New York are speed and the distance of the virtual source from Ithaca, New York are calculated on a monthly basis from MAP3S data. All eight ions of interest are estimated from a central source which only emits $SO_4^=$. In other words, the source strength, windspeed and distance are calculated from $SO_4^=$ data only. Although four sources of input data are available for use in the model, only the two MAP3S sites are incorporated. The UAPSP and NADP sites are not used. The UAPSP site being less than 200 meters from the BMA/BMN sites was considered too close, and was therefore rejected as a modeling site. The NADP site was rejected because it was not active for the entire duration of the RILWAS program.

The major drawback of the OSAWD model is its inability to take into account topographic effects. Rogowski reported that his model estimates differ significantly from actual measurements. He attributed this to ROGO's leveling out of surface features. Work done on terrain classification by Van Dop (30) in the Netherlands can easily be incorported into the OSAWD model. However, a detailed description of the terrain in a 20 km^2 area around each site is necessary. These data were not available for the initial model and could be added later. The necessary parameter estimates could not be determined with existing data, and this too will ultimately effect the accuracy of the OSAWD model.

Because neither the ROGO quantity model nor the OSAWD quality model take into account the surface effects of the receptor sites, these will tend to increase the model errors in the same direction.

CHAPTER IV

DISCUSSION

Error Analysis

Demming (37) defines the mean square error or variance of a function of several variables as:

$$\sigma_F^2 = (F_x\sigma_x)^2+(F_y\sigma_y)^2+(F_z\sigma_z)^2+2(F_xF_y\sigma_x\sigma_zV_{xy}+F_xF_z\sigma_x\sigma_yV_{xz}+ F_yF_z\sigma_y\sigma_zV_{yz}) \quad (25)$$

where σ_F^2 = the variance of mean square error

$\dot{F}_i$ = the partial differential of the function with respect to component i

σ_i^2 = variance of i

V_{ij} = the correlation between i, j

Using Demming's definition and assuming that $V_{ij} = 0$ the equation for mean square error becomes

$$\sigma_{DEP}^2 = \partial DEP/\partial Q\sigma_Q + \partial DEP/\partial C\sigma_C \quad (26)$$

where DEP = loading (ueq/l)

Q = precipitation (cm)

C = ion concentration (ueq/l)

This equation may be further expanded:

$$\sigma_{DEP}^2 = \partial DEP/\partial Q[(\partial Q/\partial SE)\sigma_{SE} + (\partial Q/\partial ME + (\partial Q/\partial TE)\sigma_{TE} + (\partial Q/\partial CE)\sigma_{CE}] + \partial DEP/\partial C[(\partial/\partial TE + (\partial C/\partial ME)\sigma_{ME} + (\partial C/\partial AE)\sigma_{AE} + (\partial C/\partial RE)\sigma_{RE} + (\partial C/\partial tiE)\sigma_{tiE}] \quad (27)$$

where SE = sampling error (cm)

ME = error in measurement (cm)

TE = errors due to topological factors (cm)

AE = areal errors (cm)

RE = averaging errors (cm)

tiE = time errors (cm)

Precipitation Errors

Errors in precipitation measurement may be broken up into three types:

(1) sampling errors

(2) errors in measurement

(3) discretization errors

Sampling errors occur when a storm cell is localized in a small region. It is possible that a storm occurred but that it was in such a small area that it was not detected by the gage network, or it is possible that the storm cells were locally heavy over part of the network which would tend to bias the entire rain gage network. Many authors have examined this subject and several methods of estimation have been proposed. I have chosen to use Huff's (20) equation

$$\ln E = 1.3132 + 0.72 \ln Pm + 0.73 \ln G - 0.56 \ln A \quad (28)$$

where E = sampling error (in^2)

Pm = average rainfall (in)

G = gauging rate ($gages/in^2$)

A = area (mi^2)

because it is the simplest to use and the only one which takes into account monthly averages. The others are only good for single events.

Errors in measurement have been studied by Woodley, et al. (25) They estimated an average maximum error over all rainfall amounts of 8.6%. Huff (38) studied several different rain gages and estimated the average error to be 2%. However, Huff exercised exceptional care in data analysis, data were analyzed omitting all the observations occurring within one day of a previous rain. Silverman & Rodgers (21) conclude that this would be the minimum expected error.

I chose to use a monthly average error in measurement of 8.6%. Although both Huff & Woodley, et al. agree that error is measured over a function of total rainfall, I decided that the increase in accuracy from using an average error in measurement over each site would not be significant, given the total uncertainties involved.

Huff estimated the errors in measurement during the summer months in order to eliminate snow. However, the error in measurement during periods of snowfall must be taken into account, Larsen & Peck (27) have developed a snow correction factor (SCF) due to wind speed. These factors typically range from 1.27 to 1.41 over a typical winter season (November through March). Because no information is available on local wind speeds at any of the RILWAS sites, I chose a winter factor of 1.27 (the minimum) multiplied by the 8.6% error used for summer measurement errors. The resultant error estimate of 10.9% is used for all of the winter months (November through March). Larson & Peck analyzed the data for Concord, N.H. and estimated a SCF of approximately 1.37.

Bras and Rodriguez-Iturbe (16) evaluated the mean square error due to discretization of the sample points. This error is estimated as 0.00072cm. An error associated with the variation due to time and space has also been estimated using graphical methods and a grand standard deviation provided by Pagnotti and Rao (39). This error is 0.0018 cm. These two errors are added together to form the discretization error. It should be noted that the discretization error is not significant.

Although the orographic effects are not errors, information on these effects are not available and therefore some errors are induced from these effects. Spreen estimated that these errors could be as much as 88% of the variance. However, since Spreen was working in the Rocky Mountains at elevations of 4,500 to 11,500 ft. with slopes between 1,000 ft/5 mi. to 5,000 ft/5 mi., it is doubtful that any type of error could be extrapolated to the Adirondacks where elevations range from 110 ft. to 2,020 ft.

Rogowski developed an error analysis based on what he called "the nearest neighbor approach." In this procedure, he would delete values from the completed matrix and then estimate the value at that point using the double linear interpolation. He then defined error as a percent deviation. While this nearest neighbor approach may have some value, possibly in determining orographic effects, I have rejected it in my error analysis because it is not clear here exactly what this error analysis is telling us.

The Rogo Quantity Model

The ROGO quantity model as developed by Rogowski and used by

Garrity contains an error which when corrected, enhances the accuracy of the model. By the original Rogoswki model, the squares in the x direction were determined by the latitude in both degrees in minutes. The latitude in degrees sets the point in either the first 11 boxes (boxes 1-11) or the second 11 boxes, (boxes 12-22). The minutes of latitude were used to fill in the boxes between 1 and 11 and 12 and 22. However, Rogowski split his boxes up into boxes with 7.5 minutes latitude on a side. His intent was to make a box that was 7.5 minutes x 7.5 minutes based on a minutes of longitude. Unfortunately, a minute of latitude at 42 to 44 degrees is not equal to a minutes of longitude but is 11/8 times larger. This error resulted in the filling of only the first seven boxes in either half, i.e., boxes 1-8 and 12-19) leaving the ROGO program to fill in the boxes 9-11 and 20-22. Tables 1-4 show the actual rainfall, the corrected ROGO estimates, the percent deviation and the estimated error using my error analysis.

Comparing estimated error with the actual deviation of the corrected ROGO model, we find that 31 out of 85 or about 36% are outside the bounds of the estimated errors. These differences are possibly caused by two factors; (1) debris falling in the weighing rain gage which would inject error into the measured rainfall amount at each site and (2) orographic effects.

According to the logbooks used by the field observers during the RILWAS program, there is no indication that an attempt was made to investigate or correct for the amount of debris in the rain gage, even when large amounts of debris were found in the wet or dry collectors. Considering the debris found in the wet and dry collectors, it becomes

Table 1

Precipitation Estimates at Big Moose

Date	Actual Rainfall (in cm)	Estimated* Rainfall (in cm)	Percent Deviation	Estimated Error
7/82	6.50	6.07	-6.64	18.39
8/82	11.43	12.32	7.78	20.07
0/82	10.95	11.20	2.32	19.87
10/82	8.36	8.25	-1.22	18.88
11/82	14.99	13.44	-10.34	23.97
12/82	11.15	9.12	-18.22	22.27
1/83	7.75	6.40	-17.38	21.01
2/83	5.94	4.39	-26.07	20.65
3/83	7.16	6.40	-10.64	20.85
4/83	19.43	16.03	-17.52	23.68
5/83	16.28	12.32	-24.34	22.24
6/83	6.50	6.73	0.52	18.39
7/83	9.07	6.65	-26.61	19.12
8/83	14.25	16.26	14.08	21.31
0/83	6.65	7.21	8.40	18.42
10/83	10.13	9.52	-6.02	19.53
11/83	17.20	13.34	-22.45	24.98
12/83	14.82	22.12	-10.85	28.43
1/84	5.79	4.88	-15.79	20.64
2/84	11.58	8.56	-26.10	22.46
3/84	6.96	5.61	-19.34	20.81
4/84	11.89	9.65	-18.80	20.26
5/84	13.79	15.11	9.58	21.11
6/84	6.63	6.55	-1.15	18.42

*Corrected ROGO model

Table 2

Precipitation Estimates at Clear Lake

Date	Actual Rainfall (in cm)	Estimated* Rainfall (in cm)	Percent Deviation	Estimated Error
8/82	9.47	8.48	-10.46	19.28
9/82	5.61	6.35	13.12	18.31
10/82	5.66	3.78	-33.18	18.31
11/82	8.00	9.75	21.90	21.09
12/82	4.70	3.63	-22.70	20.73
1/83	5.66	6.48	14.35	20.63
2/83	4.52	4.80	6.18	10.78
3/83	4.11	8.86	115.43	20.95
4/83	14.76	14.53	-1.55	21.54
5/83	13.06	15.67	20.04	20.78
6/83	4.60	6.78	47.51	18.43
7/83	10.01	3.90	-51.02	19.48
8/83	9.60	16.28	69.58	19.32
9/83	6.55	6.20	-5.43	18.40
10/83	9.17	8.97	-2.22	19.16
11/83	18.08	14.68	-18.82	25.38
12/83	20.29	14.20	-30.04	26.39
1/84	3.68	2.92	-20.69	21.24
2/84	8.33	6.40	-23.17	21.19
3/84	7.24	5.99	-17.19	20.87
4/84	12.04	8.13	-32.49	20.33
5/84	14.43	11.07	-23.24	21.39
6/84	8.84	6.05	-31.61	19.04

*Corrected ROGO model

Table 3

Precipitation Estimates at Paul A. Smith

Date	Actual Rainfall (in cm)	Estimated* Rainfall (in cm)	Percent Deviation	Estimated Error
8/82	14.17	10.08	-28.85	21.28
9/82	9.91	9.47	-4.36	19.44
10/82	6.27	4.65	-25.91	18.36
11/82	12.29	11.36	-6.82	22.76
12/82	7.26	5.77	-20.63	20.88
1/83	4.90	4.04	-17.62	20.68
2/83	4.90	3.76	-23.32	20.68
3/83	4.19	4.60	9.70	20.91
4/83	14.68	12.32	-16.09	21.51
5/83	10.87	10.57	-2.80	19.83
6/83	11.48	6.58	-42.70	20.09
7/83	6.73	10.79	-60.38	18.44
8/83	11.76	8.18	-30.45	20.21
9/83	6.60	7.62	15.38	18.41
10/83	5.33	8.71	63.33	18.31
11/83	12.60	11.40	-9.48	22.90
12/83	14.68	15.21	3.63	23.83
1/84	2.59	2.74	5.88	22.88
2/84	6.10	6.02	-1.25	20.66
3/84	3.81	3.78	-0.67	21.14
4/84	4.17	5.74	37.80	18.60
5/84	12.73	13.36	4.99	20.63
6/84	4.62	4.42	-4.40	18.43

*Corrected ROGO model

Table 4

Precipitation Estimates at Canada Lake

Date	Actual Rainfall (in cm)	Estimated* Rainfall (in cm)	Percent Deviation	Estimated Error
4/83	23.72	8.81	-62.85	25.82
5/83	17.45	16.13	-7.57	22.77
6/83	10.67	6.50	-39.05	19.75
7/83	4.32	3.30	-23.53	18.53
8/83	12.34	14.49	20.99	20.46
9/83	7.77	6.43	-17.32	18.69
10.83	9.40	8.86	-5.68	19.25
11/83	13.97	11.76	-15.82	23.51
12/83	17.09	13.79	-19.32	14.93
1/84	5.82	4.75	-18.34	20.64
2/84	8.10	7.19	-11.29	21.12
3/84	8.08	5.77	-28.62	21.11
4/84	15.29	9.83	-35.71	21.78
5/84	17.88	19.86	11.08	22.97
6/84	8.23	6.58	-20.06	18.84

*Corrected ROGO model

intriguing to speculate about possible debris in the rain gage. For example, at Big Moose large amounts of debris were found in the wet and dry collectors during May and July 1983, two months which were outside the error bounds. There were measurable amounts of pollen in wet collectors during June 1983 at the Paul A. Smith, Clear Lake and Canada Lake sites, and at the Canada Lake site during April 1983, a large amount of debris was noted. Do these records of debris correlate with possible errors in precipitation measurement? It isn't known, but it is highly likely, since the debris will contribute weight which will be recorded as precipitation.

As discussed earlier, orographic effects may cause as much as 88% of the total error. Looking at the months where deviation exceeded the estimates we find that at Paul A. Smith, Clear Lake, and Canada Lake the deviation exceeded the estimates during the months of June, July and August 1983. At Big Moose, there is an excursion during July 1983. Is this a coincidence or is it the result of frontal movement from a different direction, one in which the orographic effects are more pronounced? More data on the frontal movements through the area during the two years studied would be needed to make a determination.

Wintertime deviation (those between November and May) did not show significant negative deviation due to the wind effects on the snow. This was unexpected because of the previously discussed effects of wind on snow accumulation, but the RILWAS sites were chosen partly for their protection from the wind. Only one winter month showed a negative deviation which exceeded the estimated error, that being November 1982, at the Clear Lake site. If the snow collection factor

of 1.37 which was estimated from data taken at Concord, N.H., were used, an estimated error of 21.95% would have resulted, which is approximately the deviation
obtained.

How significant are these deviations above the maximum error? To find out, A paired T-test was performed using the means procedure from the SAS library. The results are given in Table 5. For a 5% level of significance, i.e., 95% of the values fall within the hypothesis. (Hypothesis: There is no significant difference.) CLE and PAS showed significant difference. A 1% level of significance includes Canada Lake while BMA's hypothesis becomes true at 0.05% level of significance.

Judging from the results obtained, I have chosen not to use an alternative method for making site estimates. Given the rather large errors which have been previously discussed, i.e., sampling and measurement, and the small errors from discretization, I doubt a significant improvement could be made using Kriging. The months which had errors outside the error bounds can be explained by debris in the collectors or orographic effects, neither of which can be eliminated by using a more sophisticated interpolation. An Isohyetal method could eliminate the orographic effects, but this method is hard to reproduce and may not be suitable for use on a monthly basis. In any event, it still could not account for debris in the collectors. Therefore, it is unlikely that a better method could be found to estimate the area rainfall averages.

Table 5

Results of Paired T-Test for all Sites

X	Standard Mean of Error		T	Pr > ABS(T)
		BMA/BMN		
1.128	0.3309		3.41	0.0024
		CLE		
0.587	0.6224		0.94	0.3556
		PAS		
0.490	0.4288		1.14	0.2654
		CAN		
2.328	0.9720		2.40	0.0301

Depositional Errors

The errors we are interested in can be broken into four types:

(1) errors in measurement

(2) areal errors

(3) averaging errors

(4) time errors

Using collocated concentration monitoring sites, the RILWAS BMA site and the UAPSP site #21 Garrity (33) developed a standard error in measurement for all ions. The results are given in Table 6. Garrity's standard errors are the basis for the errors in measurement.

Granat (31) studied the errors between ordinary network sampling stations, and developed curves for event, monthly and yearly standard deviation over sub areas of 30, 60, 200 and 300 km radius. Unfortunately, he chose only to publish the yearly error curves. However, he states that monthly curves are similar but the numerical values are higher. To obtain areal errors, 67% of the RSD (mean standard deviation) were taken, as per Demming (37) to estimate the areal errors. These will be somewhat low, but they should give an idea as to expected errors.

Averaging errors are somewhat tricky. We are attempting to model deposition on a monthly basis. Unfortunately, the RILWAS data base with which we are comparing our model results is sampled on a weekly basis. If the month ends at the end of a week, everything is fine, there is no error involved with the month ending. Unfortunately, this only happened four times during the two year period in question. The new months concluded with new weeks on Feb. 1, 1983, Mar. 1, 1983, Apr. 1, 1984, and Nov. 1, 1983. Of these only Feb., 1983 has no error due to ending-averaging. How do we deal with this problem? We could define one month as exactly four weeks. This would eliminate our ending by making our arbitrary months begin with the new week. However, this is aesthetically displeasing and it causes problems with the quantity portion of our model, which is based on monthly NOAA data.

Rogowski, dealt with the problem by using the following criteria: If the last day of the sample is day 4 or later of a month, the sample week is in that month. If the last day of the week is day 3 or earlier, the sample is considered part of the previous month. Rogowski felt that this was the best method because:

(1) Sample depths not volumes were available for daily basis.

(2) A low rainfall day could have the highest concentration.

(3) Consistency would be difficult to achieve from month to month.

The Rogowski method too has aesthetic problems. I choose to use the daily rainfall depths in the last week of the month in order to estimate the ending average ionic concentrations. The ionic concentrations of the week to be split up will remain the same. In other words, the weekly concentration of ions will remain constant. Rogowski's three objections need to be dealt with.

(1) Garrity (37) developed a standard error in measurement for both volume and depth sampling using collocated network stations RILWAS BMA and UAPSP #21 (as shown in Table 7). The standard error in measurement for volumes calculated from the given data is 17.6%. The

Table 6

Comparison of Mean Concentrations
RILWAS BMA UAPSPS Site 21

	Mean	Standard Deviation	Standard Error	Range High	Range Low
Volume (+)	1533	1098	271	1805	1262
	1539	1095	270	1809	1268
Inch (*)	0.95	0.66	0.16	1.12	0.79
	0.95	0.66	0.16	1.11	0.79
SO_4	72.61	51.43	13.01	85.63	59.60
	65.30	50.94	12.89	78.19	52.41
NO_3	34.23	28.63	7.24	41.48	26.99
	32.07	29.24	7.40	39.47	24.67
Cl	7.90	7.89	2.00	9.90	5.90
	4.60	5.00	1.26	5.86	3.33
NH_4	21.39	17.20	4.32	25.71	17.08
	22.74	19.14	4.80	25.54	17.94
Na	5.40	7.97	2.05	7.45	3.35
	2.67	2.90	0.75	3.42	1.92
K	2.44	2.69	0.69	3.13	1.75
	1.24	1.32	0.34	1.58	0.90
Ca	12.17	10.22	2.63	14.79	9.54
	7.50	6.43	1.65	9.15	5.84
Mg	4.00	3.44	0.88	4.89	3.12
	2.44	2.19	0.56	3.01	1.88
H	82.56	63.71	15.99	98.54	66.57
	68.13	46.71	11.72	79.85	56.41

+ Volume in ml

*Precipitation in inches

from Garrity (33)

standard error for depth measurement can be calculated as 16.8%. The difference in these errors is insignificant. (Note that Garrity's error for RILWAS' BMA site is nearly twice as large as my estimate.) Although I feel Garrity's error estimates are somewhat high, I think that the errors for volume and depth are probably proportional.

(2) In order to get an idea of the errors in assuming a constant concentration, I took the standard deviation of ions listed in the MAP3S/RAINE daily precipitation chemistry report for 15 July-21 October 1982, 1 April-30 June 1985, and 1 December-31 March 1985. Using the Demming method for estimating probable error (0.67 times the standard deviation), I arrived at possible errors for ending-averaging by taking the number of days at the end of a month in which rainfall fell but were in a week which split the month and divided this quantity by the total number of days in the month. This, multiplied by the probable error gave my estimate for the ending-averaging error. (3) In looking at the data, I do not believe that consistency would be difficult to achieve.

Depena et al. (25) found a significant bias in the data when sampling periods were extended from event to weekly samples. Because the RILWAS samples were taken on a weekly basis and MAP3S samples were taken on either a weekly or a daily basis, our data may show the same type of biases. I chose not to check these in my error analysis for two reasons (a) because I used monthly weighted ion concentration (were these on a daily or weekly sampling? The information wasn't available), (b) Did RILWAS use somewhat different analyses which would possibly remove these biases?

Although Van Dop (30) has done extensive work on this subject in Europe, little is known about the orographic effects of deposition in the U.S. In other words, can work done on the plains of Holland be transferred to the Adirondacks? It is safe to assume that there are orographic effects, but not safe to assume that these effects are the same for different topographies.

Van Dop's correction factors take into account buildings, trees, and small structures. Not enough detailed information is available in which to develop Van Dop's parameters. Furthermore, no knowledge of the type of storms which occurred during this period which would effect the $SO_4^=$ and NO_3^- concentrations as described by Bloxam, Hornbeck & Martin (28) or the direction from which the storm front approached. Without these details, the topographical errors will remain indeterminate.

Tables 7-14 show the results of both the Rogowski (ROGO) model and the OSAWD model. Comparing the estimated error with actual percent deviation for the three major ions H^+, $SO_4^=$ and NO_3^- showed that the Rogowski models show slightly better agreement with the actual measurements within the error of measurement. However, both models correlate well with each other. In addition, both show better agreement with H^+ and NO_3^- ions than with $SO_4^=$ ions. This suggests that both models are limited by the MAP3S sites. One or both of the MAP3S sites i.e., Ithaca, N.Y. or Whiteface Mountain,. N.Y. could be effected by orographic effects which would significantly effect the ion concentration at either site. Of the four sites, the Big Moose site showed the best agreement with 71% of the model estimates falling within the estimated error for NO_3^- while 79% of the ROGO estimates

Table 7

Rainfall Quality in µeq/l at Big Moose Using the OSAWD Model: Actual, OSAWD Estimate, Percent Deviation, Estimated Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
7/82	59.61	20.07	5.41	13.92	11.00	3.68	6.53	4.09	30.59
	34.56	11.76	1.64	5.79	1.98	0.57	0.78	0.22	34.18
	-42.02	-41.41	-69.69	-58.41	-82.00	-84.51	-88.06	-94.62	11.74
	26.10	50.82	43.07	51.72	30.73	32.34	37.21	36.67	65.71
8/82	97.38	26.17	4.41	11.52	9.01	7.10	4.69	5.87	65.17
	72.18	20.95	2.06	17.97	4.35	1.20	0.73	0.80	62.62
	-25.88	-19.95	-53.29	-20.20	-51.72	-83.10	-84.43	-86.37	-3.91
	13.36	29.84	46.71	21.85	31.85	14.93	45.20	14.65	25.72
9/82	59.71	20.28	2.82	13.79	5.10	1.81	2.37	1.80	35.11
	46.02	25.70	2.82	8.66	2.41	0.97	0.79	0.58	56.08
	-22.93	26.73	0.00	-37.20	-52.75	-65.48	-66.67	-67.78	59.73
	24.47	44.87	78.01	44.60	61.57	40.21	96.62	67.22	52.86
10/82	79.54	34.60	7.31	27.33	13.71	7.37	4.03	6.87	71.60
	54.99	29.56	6.94	19.95	9.48	2.48	6.70	0.99	51.87
	-30.86	-14.57	-5.06	-27.00	-30.85	-66.35	66.25	-85.59	-27.56
	19.56	29.48	31.87	26.34	24.65	16.15	60.30	21.83	28.07
11/82	43.29	29.07	4.49	10.36	5.21	2.33	4.54	2.04	67.62
	35.19	14.95	6.00	8.53	3.03	1.08	3.41	0.83	49.66
	-18.71	-14.17	33.63	-17.66	-41.84	-53.65	-24.89	-59.31	-26.56
	31.19	26.87	45.88	47.49	55.09	45.49	46.70	42.16	24.79

Table 7 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
12/82	37.28	31.37	5.43	13.60	5.08	3.03	4.05	1.77	62.91
	27.88	32.66	8.30	9.34	3.69	1.16	4.25	0.94	59.99
	-25.21	4.11	52.85	-31.32	-27.36	-61.72	4.94	-44.89	-4.64
	40.48	30.76	41.80	49.12	64.17	38.28	58.27	76.27	30.73
1/83	33.70	30.70	5.55	13.57	9.31	1.65	3.04	0.85	47.13
	17.34	31.31	7.74	4.94	5.19	1.54	3.82	0.87	39.49
	-47.56	2.12	39.46	-63.60	-44.25	-6.67	25.66	2.35	-16.21
	47.50	35.05	43.06	56.96	37.49	73.94	82.24	194.12	44.28
2/83	46.47	40.93	5.90	16.13	6.68	2.07	3.46	0.75	41.22
	27.41	35.36	9.46	6.83	4.36	1.02	2.17	0.47	46.74
	-41.02	-13.61	60.34	-57.66	-34.73	-50.72	-37.28	-37.33	13.39
	35.21	27.17	41.19	50.09	53.44	59.90	73.70	233.33	51.89
3/83	21.11	17.18	3.71	5.64	5.25	1.14	4.09	0.58	25.91
	23.53	14.53	1.66	9.50	2.93	0.61	0.84	0.23	23.56
	11.46	-15.42	-55.26	68.44	-44.19	-50.81	-79.46	-60.34	-9.07
	66.18	48.66	57.14	96.45	56.76	87.90	53.55	174.14	67.66
4/83	28.24	18.37	3.68	7.25	5.46	1.52	4.07	0.78	37.26
	40.09	19.08	2.78	12.70	4.41	1.14	1.27	0.46	46.15
	44.83	3.86	-24.46	75.17	-19.12	-25.00	-68.80	-41.03	23.86
	55.67	56.56	63.86	101.79	62.45	78.95	60.20	198.72	54.64
5/83	61.33	29.01	3.35	19.41	9.28	2.19	3.26	1.72	63.10
	48.97	22.83	3.85	13.70	4.49	1.34	1.48	0.48	54.48
	-20.15	-21.20	14.93	-29.42	-51.62	-38.81	-54.60	-72.09	-13.66
	22.01	26.92	61.49	25.35	30.93	48.40	65.03	50.00	26.56

Table 7 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
6/83	119.84	42.53	6.62	41.50	17.47	8.02	2.98	2.13	99.17
	101.64	26.08	3.95	28.67	5.02	1.11	0.53	0.56	101.83
	-15.19	-38.68	-40.33	-30.92	-71.17	-86.16	-82.21	-73.71	2.68
	12.19	21.40	33.23	14.82	17.97	14.09	76.85	56.81	18.72
7/83	98.87	28.22	7.41	17.13	12.47	6.39	3.67	1.64	96.19
	49.36	23.69	2.04	23.46	9.48	2.35	0.61	1.92	43.73
	-50.08	-16.05	-72.54	36.95	-23.98	-63.22	-83.38	17.07	-54.54
	16.22	38.13	32.17	45.13	27.99	19.09	68.12	100.61	21.70
8/83	98.03	31.54	16.91	21.29	15.68	2.23	1.73	1.71	147.05
	62.75	25.05	2.57	17.31	3.56	0.88	0.38	1.13	68.29
	-35.99	-20.58	-84.80	-18.65	-77.30	-60.54	-78.03	-33.92	-53.56
	14.25	26.51	12.54	25.55	19.01	48.88	126.59	59.06	11.91
9/83	35.53	16.46	2.65	12.43	6.11	1.55	2.56	0.60	28.45
	30.62	11.71	2.79	6.91	3.00	1.15	2.14	1.35	33.60
	-13.32	-28.86	5.28	-44.41	-50.90	-18.71	-16.41	125.00	18.10
	42.47	58.63	85.66	53.74	53.36	74.84	92.19	225.00	67.94
10/83	31.20	18.55	3.54	12.96	8.92	1.84	2.07	0.57	54.91
	37.12	17.94	3.70	6.65	4.15	1.40	2.01	1.75	48.75
	18.97	-3.29	4.52	-48.69	-53.48	-23.91	-2.90	207.02	-11.38
	41.73	39.14	56.50	33.87	30.83	55.98	99.03	124.56	29.08
11/83	18.93	21.08	1.66	6.41	4.07	1.61	2.55	0.67	35.48
	20.13	15.44	2.03	5.33	0.79	0.32	0.62	0.69	34.78
	6.34	-26.76	22.29	-16.85	-80.59	-80.12	-75.69	2.99	-2.08
	74.64	40.56	128.92	87.68	74.20	68.32	87.06	158.21	50.17

Table 7 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
12/83	12.82	16.94	2.42	3.03	2.71	0.99	2.79	3.73	23.74
	9.80	10.49	2.30	1.42	0.93	0.48	0.77	0.54	22.79
	-23.62	-38.08	-4.96	-53.14	-65.68	-51.52	-72.40	-85.52	-4.09
	121.28	60.21	96.28	237.62	124.72	120.20	87.10	40.21	84.67
1/84	28.19	49.65	5.01	11.60	5.57	2.09	3.53	0.39	64.14
	13.10	22.71	3.08	3.85	1.24	0.26	1.01	0.30	31.64
	-53.53	-54.26	-38.52	-66.81	-77.74	-87.56	-71.39	-23.08	-50.67
	47.89	15.73	41.12	42.41	51.53	50.72	60.06	220.51	26.13
2/84	34.12	41.21	4.50	13.92	8.09	2.03	3.63	0.32	49.68
	22.38	27.80	3.84	10.08	1.26	0.51	1.72	0.39	43.89
	-32.94	-32.54	-14.67	-27.59	-84.43	-75.46	-52.62	21.87	-11.65
	41.41	20.75	47.56	40.37	37.33	52.88	61.16	331.25	35.81
3/84	31.88	30.49	3.09	9.12	7.10	2.40	3.18	0.93	36.17
	19.27	18.63	3.22	4.60	11.00	2.57	5.28	0.35	20.02
	-39.55	-38.90	166.02	-49.56	54.93	7.08	66.04	-62.37	-44.65
	48.81	33.45	75.40	78.95	47.61	49.58	76.42	161.29	55.57
4/84	32.58	19.00	1.90	7.56	8.71	1.77	2.80	0.95	42.89
	37.24	30.01	2.46	8.34	17.87	0.60	0.37	0.36	66.58
	14.30	57.95	-15.17	10.32	105.17	-66.10	-86.79	-62.11	55.23
	39.96	38.21	68.97	58.07	31.57	58.19	73.21	74.74	37.28

Table 7 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
5/84	65.25	29.83	3.50	21.87	16.80	4.38	1.87	1.81	55.50
	43.13	21.39	2.31	16.66	7.51	1.54	0.67	0.81	40.53
	-33.89	-28.29	-34.00	-23.82	-55.30	-64.84	-64.17	-55.25	-26.97
	22.15	29.90	62.29	27.30	18.45	25.57	120.86	64.09	32.97
6/84	39.96	21.81	3.96	15.30	11.92	3.65	2.36	3.85	35.83
	54.39	28.01	3.54	17.86	6.16	1.63	1.27	0.63	64.00
	36.11	28.43	-10.61	16.73	-48.32	-55.34	-46.19	-83.64	78.62
	39.34	47.64	59.34	48.24	28.61	32.88	103.81	40.26	56.82

Table 8

Rainfall Quality in μeq/l at Clear Lake Using the OSAWD Model:
Actual, OSAWD Estimate, Percent Deviation, Estimating Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	NA	K	H
8/82	86.77	27.19	3.41	22.87	8.67	4.18	2.80	2.10	68.23
	27.02	9.19	1.28	4.53	1.55	0.45	0.61	0.17	26.72
	-68.86	-66.20	-62.46	-80.19	-82.12	-89.23	-78.21	-91.90	-60.84
	17.93	37.51	68.33	31.48	38.99	28.47	86.79	71.43	29.46
9/82	52.84	20.26	3.94	11.58	4.05	1.48	2.74	0.92	34.72
	56.73	16.46	1.62	14.12	3.42	0.94	0.57	0.63	49.22
	7.36	-18.76	-58.88	21.93	-15.56	-36.49	-79.20	-31.52	41.76
	25.55	38.55	52.28	42.49	70.86	71.62	77.37	93.48	48.27
10/82	62.68	29.14	6.70	19.53	5.59	2.21	2.73	1.15	73.36
	45.35	25.33	2.78	8.53	2.37	0.95	0.78	0.57	55.26
	-27.65	-13.07	-58.51	-56.32	-57.60	-57.01	-71.43	-50.43	-24.67
	23.31	31.23	32.84	31.49	56.17	51.13	83.88	105.22	25.30
11/82	49.01	30.63	4.98	13.74	5.04	2.34	5.08	0.81	71.60
	53.00	28.49	6.69	19.23	9.14	2.39	6.46	0.95	49.99
	8.14	-6.99	34.34	39.96	81.35	2.14	27.17	17.28	-30.18
	31.75	33.30	46.79	52.40	67.06	50.85	47.83	185.19	28.07
12/82	35.75	30.10	5.79	10.42	5.39	2.22	4.00	0.42	58.56
	32.55	23.07	5.59	7.89	2.80	1.00	3.15	0.77	45.94
	-8.95	-23.36	-4.15	-24.28	-48.05	-54.95	-21.95	83.33	-21.55
	37.76	25.95	35.58	47.22	53.25	47.75	53.00	204.76	28.62
1/83	17.22	14.86	4.47	6.46	4.29	1.12	2.36	0.35	26.08
	27.56	32.29	8.21	9.23	3.65	1.15	4.21	0.93	59.31
	60.05	117.29	83.67	41.88	-14.92	2.68	78.39	165.71	127.42
	87.63	64.94	50.94	103.41	75.99	103.57	100.00	385.71	74.12

Table 8 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	NA	K	H
2/83	24.46	12.58	6.57	5.27	2.55	2.34	5.93	0.58	28.86
	16.65	29.58	7.31	4.67	4.90	1.45	3.60	0.82	37.27
	-31.93	135.14	11.16	-11.39	92.16	-38.03	-39.29	41.38	29.14
	65.58	85.53	36.38	146.68	136.86	52.14	42.14	284.48	72.31
3/83	45.48	33.98	10.50	18.50	7.52	3.47	8.65	0.62	37.35
	26.93	34.74	9.30	6.71	4.29	1.00	2.13	0.46	45.92
	-40.79	2.24	-10.23	-63.73	-42.95	-71.18	-75.38	-25.81	22.95
	35.97	32.73	23.46	43.68	47.47	35.73	29.48	282.26	57.27
4/83	32.76	22.07	8.28	11.22	6.55	2.84	8.11	0.53	40.71
	17.62	10.88	1.24	7.12	2.20	0.46	0.63	0.17	17.64
	-46.21	-50.70	-85.02	-36.54	-66.41	-83.80	-92.23	-67.92	-56.67
	42.64	37.88	25.60	48.48	45.50	38.38	27.00	190.57	43.06
5/83	54.09	22.93	2.50	14.73	3.13	1.07	1.48	0.80	57.86
	40.44	18.86	2.75	12.56	4.36	1.13	1.25	0.45	45.62
	-25.24	-17.75	10.00	-14.73	39.30	5.61	-15.54	-43.75	-21.15
	29.06	45.31	94.00	50.10	108.95	112.15	165.54	193.75	35.19
6/83	90.67	28.40	4.36	33.53	10.20	3.18	2.16	1.41	71.76
	44.47	20.73	3.50	12.44	4.08	1.21	1.34	0.44	49.48
	-50.95	-27.01	-19.71	-62.90	-60.00	-61.95	-37.96	-68.79	-32.00
	14.89	27.50	47.25	14.67	28.14	33.33	98.15	60.99	23.03
7/83	69.19	21.15	6.28	14.82	6.57	1.67	2.97	1.49	68.06
	89.72	23.03	3.49	25.31	4.43	0.98	0.47	0.50	89.89
	29.67	8.89	-44.43	70.78	-32.57	-41.32	-84.18	-66.44	32.07
	21.12	43.03	35.01	41.50	47.79	67.66	77.10	81.21	27.27

Table 8 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	NA	K	H
8/83	66.20	21.72	4.10	13.22	5.68	1.09	1.84	5.49	101.84
	48.80	23.42	2.02	23.19	9.37	2.32	0.61	1.90	43.23
	-26.28	7.83	-50.71	75.42	64.96	112.84	-66.85	-65.39	-57.55
	24.23	49.54	58.29	58.47	61.44	111.93	135.87	30.05	20.49
9/83	47.65	19.65	3.83	13.56	5.42	1.59	3.37	0.60	51.20
	53.16	21.22	2.18	14.67	3.01	0.75	0.32	0.95	57.85
	11.56	7.999	-43.08	8.19	-44.46	-52.83	-90.50	58.33	12.99
	29.32	42.54	55.35	40.12	54.98	68.55	64.99	168.33	34.24
10/83	47.71	21.95	5.00	12.06	13.13	4.33	3.74	5.18	28.65
	26.59	10.17	1.43	6.00	2.60	1.09	1.86	1.17	29.17
	-44.27	-53.67	-51.40	-50.25	-80.20	-74.83	-50.27	-77.41	1.32
	31.63	43.96	45.40	55.39	24.83	26.79	63.10	26.06	67.47
11/83	14.81	16.65	1.82	5.42	2.38	0.92	2.99	0.86	30.62
	36.02	17.41	3.59	6.45	4.03	1.36	1.95	1.70	47.32
	143.21	4.56	97.25	19.00	69.33	47.83	-34.78	97.67	54.54
	87.91	43.60	109.89	81.00	115.55	111.96	68.56	82.56	52.22
12/83	11.71	17.43	2.12	2.77	2.87	1.44	3.48	0.38	21.28
	17.74	13.61	1.79	4.69	0.69	0.28	0.54	0.61	30.60
	51.49	-21.91	-15.57	69.31	-75.97	-80.56	-84.48	60.53	43.80
	120.67	49.05	100.94	202.89	105.23	76.39	63.79	278.95	83.60
1/84	26.08	49.02	5.47	6.93	5.59	1.84	4.87	0.38	56.72
	9.69	10.37	2.27	1.40	0.92	0.47	0.76	0.53	22.51
	-62.85	-78.85	-58.50	-79.80	-83.54	-74.46	-84.39	39.47	-60.31
	59.66	20.81	42.60	103.90	60.47	64.67	49.90	394.74	35.44

Table 8 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	NA	K	H
2/84	32.18	31.66	7.09	8.98	7.22	2.33	6.98	0.40	41.03
	12.95	22.45	3.04	3.81	1.22	0.26	1.00	0.30	31.28
	-59.76	-29.09	-57.12	-57.57	-83.10	-88.84	-85.67	-25.00	-23.78
	41.95	24.67	29.06	54.79	39.75	45.49	30.37	215.00	40.84
3/84	21.79	22.38	2.91	5.38	4.36	1.31	3.11	0.41	32.50
	22.60	27.45	3.79	9.96	1.25	0.51	1.70	0.38	43.35
	3.72	22.65	30.24	85.13	-71.33	-61.07	-45.34	-7.32	33.38
	64.85	38.20	73.54	104.46	69.27	83.97	71.38	258.54	54.74
4/84	33.44	22.75	3.39	9.79	0.21	2.78	3.03	0.86	43.36
	15.62	15.11	6.67	3.73	8.92	2.08	4.28	0.23	16.23
	-53.29	-33.58	96.76	-61.90	*****	-25.18	41.25	-67.44	-62.57
	46.53	44.84	68.73	73.54	*****	42.81	80.20	174.42	46.36
5/84	44.65	19.21	2.14	14.76	8.82	2.47	1.08	1.94	43.26
	33.34	26.87	2.20	7.47	16.00	0.53	0.33	0.32	59.61
	-25.33	35.64	2.80	-49.39	81.41	-78.54	-69.44	-83.51	37.79
	29.16	36.65	93.46	29.74	31.18	41.70	189.81	36.60	36.96
6/84	37.24	16.81	3.37	11.06	5.31	2.12	2.67	0.99	31.39
	42.44	21.05	2.27	16.39	7.39	1.52	0.66	0.80	39.89
	13.96	25.22	-32.64	48.19	39.17	-28.30	-75.28	-19.19	27.08
	38.80	53.06	64.69	53.98	58.38	52.83	84.64	117.17	58.30

Table 9

Rainfall Quality in μeq/l at Paul A. Smith Using the OSAWD Model:
Actual, OSAWD Estimate, Percent Deviation, Estimated Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
8/82	56.20	21.16	3.44	19.89	8.37	3.22	2.62	1.25	32.95
	27.60	9.39	1.31	4.63	1.58	0.46	0.62	0.17	27.30
	-50.89	-55.62	-61.92	-76.72	-81.12	-85.71	-76.34	-86.40	-17.30
	27.69	48.20	67.73	36.20	40.38	36.96	92.75	120.00	61.00
9/82	52.03	17.43	5.27	16.51	3.37	1.28	2.82	1.13	32.29
	57.94	16.82	1.65	14.42	3.50	0.96	0.58	0.64	50.26
	11.36	-3.50	-68.69	-12.66	3.86	-25.00	-79.43	-43.36	55.56
	25.95	44.81	39.09	29.80	85.16	82.81	75.18	76.11	51.90
10/82	67.42	29.54	6.27	20.79	4.78	2.21	3.33	0.83	82.36
	45.51	25.36	2.78	8.54	2.37	0.95	0.78	0.57	55.34
	-32.65	-14.15	-55.66	-58.92	-50.42	-57.01	-76.58	-35.23	-32.81
	21.67	30.81	35.09	29.58	65.69	51.13	68.77	137.50	22.54
11/82	33.19	23.24	3.18	7.90	2.87	1.75	3.15	0.54	53.41
	53.18	28.59	6.71	19.29	9.17	2.40	6.48	0.96	50.17
	60.23	23.02	111.01	144.18	219.51	37.14	105.71	77.78	-6.07
	46.88	43.89	73.27	91.14	117.77	68.00	77.14	277.78	37.63
12/82	42.40	32.76	7.30	12.60	5.43	1.94	6.27	0.68	70.32
	32.78	23.24	5.59	7.95	2.82	1.01	3.18	0.77	46.27
	-22.69	-29.06	-23.42	-36.90	-48.07	-47.94	-49.28	13.24	-34.20
	31.84	23.84	28.22	39.05	52.85	54.64	33.81	126.47	23.83

Table 9 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
1/83	27.94	31.26	11.64	12.08	7.20	2.05	10.39	0.51	39.99
	27.59	32.32	8.22	9.24	3.65	1.15	4.21	0.95	59.37
	-1.25	3.39	-29.38	-23.51	-49.31	-43.90	-59.48	82.35	48.46
	54.01	30.87	19.50	55.30	45.28	56.59	22.71	264.71	48.34
2/83	89.42	70.30	13.95	33.12	6.69	2.12	12.56	0.66	47.91
	16.74	29.74	7.35	4.69	4.92	1.46	3.62	0.82	37.47
	-81.28	-57.70	-47.31	-85.84	-26.46	-31.13	-71.18	24.24	-21.79
	17.94	15.31	17.13	23.34	52.17	57.55	19.90	250.00	43.56
3/83	18.09	18.17	14.02	4.22	7.38	4.38	13.64	1.51	27.41
	26.98	34.80	9.31	6.72	4.29	1.00	2.13	0.46	46.00
	49.14	91.52	-33.59	59.24	-41.87	-77.17	-84.38	-69.54	67.82
	90.44	61.20	17.33	191.47	48.37	28.31	18.70	115.89	78.04
4/84	27.93	19.85	6.11	9.24	5.15	2.88	6.39	0.85	36.26
	18.06	11.15	1.28	7.30	2.25	0.47	0.65	0.18	18.09
	-35.34	-43.83	-79.05	-21.00	-56.31	-83.68	-89.83	-78.82	-50.11
	50.02	42.12	34.70	58.87	57.36	37.85	34.27	118.82	48.35
5/83	59.19	26.91	3.06	28.48	11.56	3.48	2.80	1.08	49.53
	40.48	18.88	2.76	12.57	4.36	1.13	1.25	0.45	45.67
	-31.61	-29.84	-9.80	-55.86	-62.28	-67.53	-55.36	-58.33	-7.79
	26.56	38.61	76.80	25.91	29.50	34.48	87.50	143.52	41.11
6/83	140.95	37.89	4.95	42.59	10.18	2.53	1.53	1.85	157.53
	44.87	20.92	3.53	12.55	4.11	1.23	1.35	0.44	49.92
	-68.17	-44.79	-28.69	-70.53	-59.63	-51.38	-11.76	-76/22	-68.31
	9.58	20.61	41.62	11.55	28.19	41.90	138.56	46.49	10.64

Table 9 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
7/83	72.29	28,56	5.35	21.55	8.47	2.17	2.30	1.64	70.64
	90.74	23.29	3.53	25.60	4.48	0.99	0.47	0.50	90.91
	25.52	-18.45	-39.66	18.79	-47.11	-54.38	-79.57	-69.51	28.69
	20.21	31.86	37.61	28.54	37.07	52.07	99.57	73.78	26.27
8/83	64.22	21.16	6.79	15.11	8.98	1.31	1.84	1.90	87.99
	48.85	23.45	2.02	23.22	9.38	2.32	0.61	1.90	43.27
	-23.93	10.83	-70.25	53.67	4.45	77.10	-66.35	0.00	-50.82
	24.98	50.85	35.20	51.16	38.86	93.13	135.87	86.84	23.72
9/83	39.97	17.80	2.29	14.49	3.80	1.43	1.89	0.59	49.62
	53.95	21.54	2.21	14.89	3.06	0.76	0.33	0.97	58.71
	34.98	21.01	-3.49	2.76	-55.00	-46.85	-82.54	64.41	18.32
	34.95	46.97	92.54	37.54	43.82	76.22	115.87	171.19	35.33
10/83	27.86	16.34	3.54	7.64	5.34	1.21	1.77	0.47	24.20
	26.93	10.30	2.46	6.08	2.64	1.10	1.88	1.19	29.55
	-3.34	-36.96	-30.31	-20.42	-50.56	-9.09	6.21	153.19	22.11
	54.16	59.06	64.12	87.43	61.05	95.87	133.33	287.23	79.88
11/83	13.26	13.01	1.14	2.60	2.63	0.83	2.20	0.62	23.03
	36.12	17.46	3.60	6.47	4.04	1.36	1.96	1.70	47.45
	172.40	34.20	215.79	148.85	53.61	63.86	-10.91	174.19	106.04
	98.19	55.80	175.44	168.85	104.56	124.10	93.18	114.52	69.43
12/83	9.11	9.82	1.53	1.21	2.54	0.84	2.22	1.09	15.37
	17.95	13.77	1.81	4.75	0.70	0.28	0.55	0.61	30.96
	97.04	40.11	18.30	292.56	-72.44	-66.67	-75.23	-44/04	101.43
	155.10	87.07	139.87	464.46	118.90	130.95	100.00	97.25	115.74

Table 9 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
1/84	53.84	74.90	7.74	15.40	10.27	4.03	9.38	0.75	78.01
	9.70	10.39	2.27	1.41	0.92	0.47	0.76	0.53	22.53
	-81.98	-86.13	-70.67	-90.84	-91.04	-88.34	-91.90	-29.33	-71.12
	28.90	13.62	30.10	46.75	32.91	29.53	25.91	200.00	25.77
2/84	34.87	45.60	5.33	12.30	13.21	3.11	6.95	0.54	43.52
	12.97	22.48	3.04	3.81	1.22	0.26	1.00	0.30	31.31
	-62.30	-50.70	-42.96	-69.02	-90.76	-91.64	-85.61	-44.44	28.06
	38.72	17.13	38.65	40.00	21.73	34.03	30.50	159.26	38.51
3/84	38.90	29.21	5.31	12.05	7.78	3.21	3.19	1.16	33.07
	22.63	27.48	3.79	9.97	1.25	0.51	1.70	0.38	43.40
	-41.83	-5.92	-28.63	-17.26	-83.93	-79.24	-79.24	-67.24	31.24
	36.32	29.27	40.30	46/64	38.82	34.27	27.11	91.38	53.79
4/84	60.34	26.68	8.06	16.48	20.84	4.07	5.76	1.97	40.22
	15.92	15.39	6.79	3.80	9.09	2.12	4.36	0.29	16.53
	-73.61	-42.32	-15.76	-76.95	-56.38	-47.91	-24.04	-85.28	-58.90
	25.79	38.23	28.91	43.69	16.22	29.24	42.33	76.14	49.98
5/84	91.84	45.93	4.89	32.43	28.89	6.58	2.04	5.79	71.10
	33.68	27.24	2.22	7.54	16.16	0.54	0.34	0.32	60.21
	-63.33	-40.91	-54.60	-76.75	-44.06	-91.79	-83.33	-94.47	-15.32
	14.18	15.81	40.90	13.54	9.52	15.65	100.49	12.26	22.49
6/84	85.67	50.52	15.85	25.86	31.83	11.12	10.11	7.33	47.39
	42.51	21.08	2.28	16.41	7.40	1.52	0.66	0.80	39.95
	-50.38	-47.98	-85.62	-36.54	-76.75	-86.33	-93.47	-89.09	-15.70
	16.87	22.01	13.75	23.09	9.74	10.07	22.35	15.83	38.62

Table 10

Rainfall Quality in μeq/l at Canada Lake Using the OSAWD Model:
Actual, OSAWD Estimate, Percent Deviation, Estimated Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
4/84	69.78	41.68	8.47	18.29	16.72	5.68	9.64	1.77	70.35
	34.85	11.86	1.66	5.84	1.99	0.58	0.79	0.22	34.46
	-50.06	-71.67	-80.40	-68.07	-88.10	-89.79	0.91	-87.57	-51.02
	22.30	24.37	27.51	39.37	20.22	20.95	25.21	84.75	28.57
5/83	40.75	22.22	9.96	12.09	7.908	3.89	9.38	0.62	44.98
	72.76	21.12	2.07	18.11	4.39	1.21	0.73	0.83	63.13
	78.55	-4.95	-79.22	49.79	-44.89	-68.89	-92.22	30.65	40.35
	33.13	35.15	20.68	40.69	35.96	27.25	22.60	138.71	37.26
6/83	83.44	40.77	4.86	28.99	11.74	3.19	4.74	1.03	78.31
	46.04	25.71	2.82	8.66	2.41	0.97	0.79	0.58	56.10
	-44.82	-36.94	-41.98	-70.13	-79.47	-69.59	-83.33	-43.69	-28.36
	17.51	22.32	45.27	21.21	26.75	35.42	45.31	117.48	23.70
7/83	81.71	25.50	3.36	35.19	12.71	3.33	2.69	1.16	59.73
	55.05	29.59	6.94	19.97	9.49	2.48	6.71	0.99	51.92
	-32.63	16.04	106.55	-43.25	-25.33	-25.53	149.44	-14.66	-13.08
	19.04	40.00	69.35	20.46	26.59	35.74	90.33	129.31	33.65
8/83	82.34	33.38	10.85	23.24	18.60	4.38	4.63	1.82	68.28
	35.27	25.01	6.02	8.55	3.03	1.08	3.42	0.85	49.78
	-57.17	-25.07	-44.52	-63.21	-83.71	-75.34	-26.13	-54.40	-27.09
	16.40	23.40	18.99	21.17	15.43	24.20	45.79	47.25	24.55

Table 10 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
9/83	89.75	27.62	7.83	19.54	10.47	1.19	1.79	3.16	322.28
	27.89	32.67	8.31	9.34	3.69	1.16	4.26	0.94	60.01
	-63.92	18.28	6.13	-52.20	-64.76	-2.52	137.99	-70.25	-81.38
	16.81	34.94	28.99	34.19	31.14	97.48	131.84	42.72	6.00
10/83	55.67	20.30	4.15	16/10	6.52	1.88	3.41	0.50	82.23
	17.67	21.41	7.76	4.95	5.20	1.54	3.83	0.87	39,56
	-68.26	54.73	86.99	-69.25	-20.25	-18.09	12.32	74.00	-51.39
	28.81	53.00	57.59	48.01	53.53	64.89	73.31	330.00	25.38
11/83	38.96	20.84	8.23	10.23	7.15	4.23	7.64	2.14	29.90
	27.43	35.38	9.47	6.83	4.37	1.02	2.17	0.47	46.77
	-29.59	69.77	15.07	-33.24	-38.88	-75.89	-71.60	-78.04	56.42
	41.99	53.36	29.53	78.98	49.93	29.31	33.38	81.78	71.54
12/83	42.86	33.06	3.32	10.16	6.34	3.44	5.20	2.48	56.42
	23.76	14.67	1.68	9.60	2.96	0.61	0.85	0.12	23.79
	-44.56	-55.63	-49.40	-5.51	-53.31	-82.27	-83.65	-90.73	-57.83
	32.59	25.29	63.86	53.54	47.00	31/69	42.12	40.73	31.07
1/84	19.63	19.49	3.32	3.80	4.52	2.13	4.00	0.59	29.89
	40.92	19.09	2.79	12.71	4.41	1.13	1.27	0.46	46.17
	108.46	-2.05	-15.96	234.47	-2.43	-46.48	-68.25	-22.03	54.47
	80.08	53.31	70.78	194.21	75.44	56.34	61.25	262.71	68.12
2/84	30.22	47.39	7.21	12.17	5.37	2.58	6.24	0.46	57.26
	49.11	22.90	3.86	13.74	4.50	1.34	1.48	0.48	54.65
	62.51	-51.68	-46.46	12.90	-16.20	-48.06	-76.28	4.35	-4.56
	44.67	16.48	28.67	40.43	53.45	41.09	33.97	186.96	29.27

Table 10 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
3/84	45.38	44.14	5.90	17.96	8.62	3.24	5.14	0.62	63.54
	102.04	26.19	2.97	28.78	5.04	1.12	0.53	0.57	102.23
	124.86	-40.67	-32.71	60.24	-41.53	-65.43	-89.69	-8.06	60.89
	32.10	20.62	37.29	34.24	36.43	34.88	44.55	195.16	29.21
4/84	25.35	30.79	4.67	7.81	7.48	5.14	4.08	0.72	35.74
	49.38	23.70	2.04	23.47	9.48	2.35	0.61	1.92	43.74
	94.79	-23.03	-56.32	200.51	26.74	-54.28	-85.05	166.67	22.38
	63.27	34.95	51.18	98.98	46.66	23.74	61.27	229.17	58.39
5/84	40.13	29.18	3.70	10.34	9.59	3.83	2.25	0.71	43.96
	63.09	25.18	2.59	17.41	3.58	0.89	0.39	1.13	63.66
	57.21	-13.71	-30.00	68.47	-63.80	-76.76	-82.67	59.15	56.19
	34.81	28.65	57.30	52.61	30.13	28.46	97.33	142.25	39.88
6/84	37.82	26.55	2.87	15.64	12.17	2.95	1.50	1.34	45.11
	30.76	11.77	2.81	6.94	3.01	1.26	2.15	1.36	33.75
	-18.67	-55.67	-2.09	-55.63	-75.27	-57.29	43.33	1.49	-25.18
	39.90	36.35	79.06	42.71	26.79	39.32	157.33	100.75	42.85

Table 11

Rainfall Quality in μeq/l at Big Moose Using the ROGO Model:
Actual, ROGO Estimate, Percent Deviation, Estimated Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
7/82	59.61	20.07	5.41	13.92	11.00	3.68	6.53	4.09	30.59
	52.12	18.17	2.88	10.03	3.96	1.23	6.53	0.75	49.30
	-12.57	-9.44	-46.67	-27.95	-64.00	-66.58	-68.84	-81.78	61.15
	26.10	50.82	43.07	51.72	30.73	32.34	37.21	36.67	65.71
8/82	97.38	26.17	4.41	22.52	9.01	7.10	4.69	5.87	65.17
	106.88	33.72	3.39	26.87	7.58	2.07	4.69	1.66	73.09
	9.76	28.85	-23.13	19.32	-15.87	-70.85	-68.66	-71.72	12.15
	13.86	29.84	46.71	21.85	31.85	14.93	45.20	14.65	25.72
9/82	59.71	20.28	2.82	13.79	5.10	2.81	2.37	1.80	35.11
	46.42	21.61	2.20	10.27	2.50	1.00	2.37	0.85	52.88
	-22.26	6.53	-21.81	-25.49	-51.08	-64.59	-50.63	-52.50	50.61
	24.47	44.87	78.01	44.60	61.57	40.21	96.62	67.22	52.86
10/82	79.54	34.60	7.31	27.33	13.71	7.37	4.03	6.87	71.60
	56.35	25.27	5.02	18.01	6.68	1.82	4.03	1.33	54.19
	-29.16	-26.98	-31.33	-34.10	-51.28	-75.31	4.59	-80.57	-24.32
	19.56	29.48	31.87	26.34	24.65	16.15	60.30	21.83	28.07
11/82	43.29	29.07	4.49	10.36	5.21	2.33	4.54	2.04	67.62
	37.48	24.67	5.22	8.75	3.09	1.12	4.54	0.93	51.11
	-13.43	-15.14	16.37	-15.54	-40.69	-51.93	-30.29	-54.17	-24.42
	31.19	26.87	45.88	47.49	55.09	45.49	46.70	42.16	24.79
12/82	37.28	31.37	5.43	13.60	5.08	3.03	4.05	1.77	62.91
	28.61	29.94	6.21	7.33	3.03	0.99	4.05	0.82	58.32
	-23.26	-4.54	14.46	-46.07	-40.35	-67.16	-21.23	-53.67	-7.25
	40.48	30.76	41.80	49.12	64.17	38.28	58.27	76.27	30.73

Table 11 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
1/83	33.70	30.70	5.55	13.57	9.31	1.65	3.04	0.85	47.13
	18.41	25.51	6.33	6.25	4.14	1.29	3.04	0.76	35.16
	-45.37	-16.89	14.14	-53.91	-55.48	-21.82	21.05	-10.59	-25.40
	47.60	35.05	43.06	56.96	37.49	73.94	82.24	194.12	44.28
2/83	46.47	40.93	5.90	16.13	6.68	2.07	3.46	0.75	41.22
	27.71	32.77	7.92	7.97	4.28	1.04	3.46	0.45	44.37
	-40.37	-19.95	34.32	-50.56	-35.85	-49.76	26.59	-40.67	7.64
	35.21	27.17	41.19	50.09	53.44	59.90	73.70	233.33	51.89
3/83	21.11	17.18	3.71	5.64	5.25	1.24	4.09	0.58	25.91
	42.01	25.82	4.74	15.27	5.29	1.40	4.09	0.58	42.33
	99.03	50.29	27.76	170.66	0.86	12.50	8.19	0.00	63.35
	66.18	48.66	57.14	96.45	56.76	87.90	53.55	174.14	67.66
4/83	28.24	18.37	3.68	7.25	5.46	1.52	4.07	0.78	37.26
	42.34	19.59	5.55	12.71	5.07	1.70	4.07	0.49	44.06
	49.93	6.64	50.82	75.24	-7.14	12.17	-9.46	-37.18	18.25
	55.67	56.56	63.86	101.79	62.45	78.95	60.20	198.72	54.64
5/83	61.33	29.01	3.35	19.41	9.28	2.19	3.26	1.72	63.10
	53.29	24.44	4.18	15.01	4.29	1.32	3.26	0.59	59.54
	-13.12	-15.75	24.78	-22.67	-53.77	-39.73	-45.40	-65.41	-5.64
	22.01	26.92	61.49	25.35	30.93	48.40	65.03	50.00	26.56
6/83	119.84	42.53	6.62	41.50	17.47	8.02	2.98	2.13	99.17
	115.09	32.08	4.06	34.64	6.31	1.47	2.98	3.91	117.06
	-3.96	-24.57	-38.67	-16.53	-63.88	-81.67	-71.98	83.80	18.04
	12.19	21.40	33.23	14.82	17.97	14.09	76.85	56.81	18.72

Table 11 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
7/83	98.57	28.22	7.43	17.13	12.47	6/39	3.67	1.64	96.19
	53.34	24.43	7.20	18.84	8.70	1.92	3.67	1.99	41.88
	-46.05	-13.43	-3.16	9.98	-30.19	-69.95	-83.92	21.04	-56.46
	16.22	38.13	32.17	45.13	27.99	19.09	68.12	100.61	21.70
8/83	98.03	31.54	16.91	21.29	15.68	2.23	1.73	1.71	147.05
	76.43	29.75	2.88	20.57	4.95	1.22	1.73	1.56	80.77
	-22.03	-5.66	-82.97	-3.41	-63.43	-45.52	-67.05	-8.48	-45.07
	14.25	26.51	12.54	25.55	19.01	48.83	126.59	59.06	11.92
9/83	35.53	16.46	2.65	12.43	6.11	1.55	2.56	0.60	28.45
	35.62	15.24	3.10	9.70	4.51	1.49	2.56	1.45	39.44
	0.25	-7.38	16.98	-21.19	-26.19	-3.87	-11.13	140.83	38.65
	42.47	58.63	85.66	53.74	53.36	74.84	92.19	115.00	67.94
10/83	31.20	18.55	3.54	12.96	8.92	1.84	2.07	0.57	54.98
	37.83	18.50	3.77	9.11	6.57	2.58	2.07	5.30	44.31
	21.27	-0.24	6.64	-29.67	-26.35	40.49	-8.21	829.82	-19.42
	41.73	39.14	56.50	33.87	30.83	55.98	99.03	124.56	29.08
11/83	18.93	21.08	1.66	6.41	4.07	1.61	2.55	0.67	35.46
	22.86	15.46	2.23	5.54	0.96	0.46	2.55	0.78	38.42
	20.76	-26.68	34.64	-13.57	-76.41	-71.43	-69.02	16.42	8.36
	74.64	40.56	128.92	87.68	74.20	68.32	87.06	158.21	50.17
12/83	12.83	16.94	2.42	3.03	2.71	0.99	2.79	3.73	23.74
	11.48	12.33	2.40	1.60	0.75	0.45	2.79	0.49	23.88
	-10,52	-27.18	-0,62	-47.19	-72.32	-54.04	-70.79	-86.86	0.61
	121.28	60.21	96.28	237.62	124.72	120.20	87.10	40.21	84.67

Table 11 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
1/84	28.19	49.65	5.01	11.60	5.57	2.09	3.53	0.39	64.14
	21.07	35.59	3.99	6.96	1.87	0.42	3.53	0.38	48.69
	-25.26	-28.31	-20.26	-39.96	-66.43	-79.90	-69.41	-1.28	-24.10
	47.89	15.73	41.12	42.41	51.53	50.72	60.06	220.51	26.13
2/84	34.12	42.12	4.50	13.92	8.09	1.03	3.63	0.32	49.68
	23.05	28.20	3.25	8.63	1.23	0.53	3.63	3.30	45.46
	-32.44	-31.58	-27.89	-37.64	-84.73	-74.52	-17.91	929.69	-8.50
	41.41	20.75	47.56	40.37	37.33	52.85	61.16	331.25	35.81
3/84	31.88	30.49	3.09	9.12	7.10	2.40	3.18	0.93	36.17
	26.01	23.31	9.02	6.12	13.34	2.82	3.18	1.69	28.28
	-18.40	-23.55	191.91	-32.89	87.96	17.71	192.61	81.72	-21.81
	48.81	33.45	75.40	78.95	47.61	49.58	76.42	161.29	55.57
4/84	32.58	19.00	2.90	7.56	8.71	1.77	2.80	0.95	42.89
	41.30	31.40	3.45	9.55	13.50	0.80	2.80	0.49	65.00
	26.76	65.26	18.97	26.32	54.99	-54.80	-64.29	-48.42	51.55
	39.96	38.21	68.97	58.07	31.57	58.19	73.21	74.74	37.28
5/84	65.24	29.83	3.50	21.87	16.80	4.38	1.87	1.81	55.50
	43.55	21.01	9.95	19.10	6.60	1.60	1.87	0.85	38.05
	-33.25	-29.57	184.29	-12.67	-60.71	-63.47	-62.57	-53.31	-31.44
	22.15	29.90	62.29	27.30	18.45	25.57	120.86	64.09	32.97
6/84	39.96	21.81	3.96	15.30	11.92	3.65	2.36	3.85	35.83
	55.90	26.75	3.70	20.85	5.90	1.60	2.36	1.05	57.10
	39.89	22.65	-6.57	36.27	-50.50	-56.16	-2.54	-72.73	59.36
	39.34	47.64	59.24	48.24	28.61	32.88	103.81	40.26	56.82

Table 12

Rainfall Quality in μeq/l at Clear Lake Using the ROGO Model:
Actual, ROGO Estimate, Percent Deviation, Estimated Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
8/82	86.77	27.19	3.41	22.87	8.67	4.18	2.80	2.10	68.13
	52.12	18.17	2.88	10.03	3.96	1.23	2.80	0.75	49.30
	-39.93	-33.16	-15.40	-56.14	-54.33	-70.57	-27.32	-64.52	-27.75
	17.93	37.51	68.33	31.48	38.99	28.47	86.79	71.43	29.46
9/82	52.84	20.26	3.94	11.58	4.05	1.48	2.74	0.92	34.72
	106.88	33.72	3.39	26.87	7.58	2.07	2.74	1.66	73.09
	102.27	66.44	-13.96	132.04	87.16	39.86	-46.35	80.43	110.51
	25.55	38.55	52.28	42.49	70.86	71.62	77.37	93.48	48.27
10/82	62.68	29.14	6.70	19.53	5.59	2.21	2.73	1.15	73.36
	46.42	21.61	2.20	10.27	2.50	1.00	2.73	0.85	52.88
	-25.94	-25.85	-67.09	-47.39	-55.37	-54.98	-57.14	-25.65	-27.92
	23.31	21.23	32.84	31.49	56.17	51.13	83.88	105.22	25.30
11/82	49.01	30.63	4.98	13.74	5.04	2.34	5.08	0.81	71.60
	56.35	25.27	5.02	18.01	6.68	1.82	5.08	1.33	54.19
	14.97	-17.52	0.80	31.08	32.54	-22.22	-17.03	64.81	-24.32
	31.75	33.30	46.79	52.40	67.06	50.85	47.83	185.19	28.07
12/82	35.75	30.10	5.79	10.42	5.39	2.22	4.00	0.42	58.56
	37.48	24.67	5.22	8.75	3.09	1.12	4.00	0.93	51.11
	4.83	-18.04	-9.76	-16.03	-42.67	-49.55	-20.88	122.62	-12.73
	37.76	25.95	35.58	47.22	53.25	47.75	53.00	204.76	28.62
1/83	17.22	14.86	4.47	6.46	4.29	1.12	2.36	0.35	26.08
	28.61	29.94	6.21	7.33	3.03	0.99	2.36	0.82	58.35
	66.14	101.51	39.04	13.54	-29.37	-11.16	35.17	134.29	123.73
	87.63	64.94	50.78	103.41	75.99	103.57	100.00	385.71	74.12

Table 12 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	NA	K	H
2/83	24.46	12.58	6.57	5.27	2.55	2.34	5.93	0.58	28.86
	18.41	25.51	6.33	6.25	4.14	1.29	5.93	0.76	35.16
	-24.73	102.82	-3.58	18.69	62.55	-44.87	-37.94	31.03	21.83
	65.58	85.53	33.38	146.68	136.86	52.14	42.16	284.48	72.31
3/83	45.48	33.98	10.36	18.50	7.52	3.47	8.65	0.62	37.35
	27.71	32.77	7.92	7.97	4.28	1.04	8.65	0.45	44.37
	-39.07	-3.58	-23.50	-56.89	-43.02	-70.03	-49.36	-28.23	18.80
	35.97	32.73	23.46	43.68	47.47	35.73	29.48	282.26	57.27
4/83	32.76	22.07	8.28	11.22	6.55	2.84	8.11	0.53	40.71
	42.01	25.82	4.74	15.27	5.29	1.40	8.11	0.58	42.33
	28.25	16.99	-42.75	36.05	-19.16	-50.88	-45.44	9.43	3.97
	42.64	37.88	25.60	48.48	45.50	38.38	27.00	190.57	43.06*
5/83	54.09	22.93	2.50	14.73	3.13	1.07	1.48	0.80	57.86
	42.34	19.59	5.55	12.71	5.07	1.70	1.48	0.49	44.06
	-21.72	-14.57	122.00	-13.75	61.98	59.35	148.99	-38.75	-23.85
	29.06	45.31	94.00	50.10	108.95	112.15	165.54	193.75	35.19
6/83	90.67	28.40	4.36	33.53	10.20	3.13	2.16	1.41	72.76
	53.29	24.44	4.18	15.01	4.29	1.32	2.16	0.59	59.54
	-41.23	-13.94	-4.13	-55.23	-57.94	-58.49	-17.59	-57.80	-18.17
	14.89	27.50	47.25	14.67	28.14	33.33	98.15	60.99	23.03
7/83	69.19	21.15	6.28	14.82	6.57	1.67	2.97	1.49	68.06
	115.09	32.08	4.06	34.64	6.31	1.47	2.97	3.91	117.06
	66.34	51.68	-35.35	133.74	-3.96	-11.98	-71.89	162.75	72.00
	21.12	43.03	35.03	41.50	47.79	67.66	77.10	81.21	27.27

Table 12 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	NA	K	H
8/83	66.10	21.72	4.10	13.22	5.68	1.09	1.84	5.49	101.84
	53.34	24.43	7.30	18.84	8.70	1.92	1.84	1.99	41.88
	-19.43	12.48	75.49	42.51	53.26	76.15	-67.93	-63.84	-58.88
	24.23	49.54	58.29	58.47	61.44	111.93	135.87	30.05	20.49
9/83	47.65	19.65	3.83	13.56	5.42	1.59	3.37	0.60	51.20
	76.43	29.75	2.88	20.57	4.95	1.22	3.37	1.56	80.77
	60.41	51.42	-24.80	51.66	-8.67	-23.58	-83.09	160.83	57.75
	29.32	42.54	55.35	40.12	54.98	68.55	64.99	168.33	34.24
10/83	47.72	21.95	5.00	12.06	13.13	4.33	3.74	5.18	28.65
	35.62	15.24	3.10	9.70	4.51	1.49	3.74	1.45	39.44
	-25.34	-30.55	-38.00	-19.53	-65.65	-65.59	-39.17	-72.10	37.68
	31.63	43.96	45.40	55.39	24.83	26.79	63.10	26.05	67.47
11/83	14.81	16.65	1.82	5.42	2.38	0.92	2.99	0.86	30.62
	37.83	18.50	3.77	9.11	6.57	2.58	2.99	5.30	44.31
	155.47	11.14	107.42	68.17	176.05	180.98	-36.45	516.28	44.69
	87.91	43.60	109.89	81.00	115.55	111.96	68.56	82.56	52.22
12/83	11.71	17.43	2.12	2.77	2.87	1.44	3.48	0.38	21.28
	22.86	15.46	2.23	5.54	0.96	0.46	3.48	0.78	38.42
	95.22	-11.33	5.42	100.00	-66.55	-68.06	-77.30	105.26	80.57
	120.67	49.05	100.94	202.89	105.23	76.39	63.79	278.95	83.60
1/84	26.08	49.02	5.47	6.93	5.59	1.84	4.87	0.38	56.72
	11.48	12.33	2.40	1.60	0.75	0.45	4.87	0.49	23.88
	-55.98	-74.84	-56.03	-76.91	-86.58	-75.27	-83.26	28.95	-57.89
	59.66	20.81	42.60	103.90	60.47	64.67	49.90	394.74	35.44

Table 12 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	NA	K	H
2/84	32.18	31.66	7.09	8.93	7.22	2.33	6.98	0.40	41.04
	21.07	35.59	3.99	6.96	1.87	0.42	6.98	0.38	48.69
	-34.52	12.41	-43.65	-22.44	-74.10	-81.97	-84.55	-3.75	18.63
	41.95	24.67	29.06	54.79	39.75	45.49	30.37	215.00	40.84
3/84	21.79	22.38	2.91	5.33	4.36	1.31	3.11	0.41	32.50
	23.05	28.20	3.25	8.63	1.23	0.53	3.11	3.30	45.46
	5.78	25.98	11.51	61.34	-71.67	-59.54	-4.18	703.66	39.86
	64.85	38.20	73.54	104.46	69.27	83.97	71.38	258.54	54.74
4/84	33.44	22.75	3.39	9.79	0.21	2.78	3.03	0.86	43.36
	26.01	23.31	9.02	6.12	13.34	2.82	3.03	1.69	28.28
	-22.20	2.46	166.08	-37.49	*****	1.62	207.10	96.51	-34.78
	46.53	44.84	68.73	73.54	*****	42.81	80.20	174.42	46.36
5/84	44.65	19.81	2.14	14.76	8.82	2.47	1.08	1.94	43.26
	41.30	31.40	3.45	9.55	13.50	0.80	1.08	0.49	65.00
	-7.50	58.51	61.21	-35.30	53.06	-67.61	-7.41	-74.74	50.25
	29.16	36.65	93.46	29.74	31.18	41.70	189.81	36.60	36.96
6/84	37.24	16.81	3.37	11.06	5.31	2.12	2.67	0.99	31.39
	43.55	21.01	9.95	19.10	6.60	1.60	2.67	0.85	38.05
	16.94	24.99	195.25	72.69	24.29	-24.53	-73.78	-14.65	21.22
	38.80	53.06	64.69	53.98	58.38	52.83	84.64	117.17	58.30

Table 13

Rainfall Quality in μeq/l at Paul A. Smith Using the ROGO Model:
Actual, ROGO Estimate, Percent Deviation, Estimated Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
8/82	56.20	21.16	3.44	19.89	8.37	3.22	2.62	1.25	32.95
	52.12	18.17	2.88	10.03	3.96	1.23	2.62	0.75	49.30
	-7.26	-14.11	-16.13	-49.57	-52.69	-61.80	-22.33	-40.40	49.61
	27.69	48.20	67.73	36.20	40.38	36.96	92.75	120.00	61.00
9/82	52.03	17.43	5.27	16.51	3.37	1.28	2.82	1.13	32.29
	106.88	33.72	3.39	26.87	7.58	2.07	2.82	1.66	73.09
	105.42	93.46	-35.67	62.75	124.93	61.72	-47.87	46.90	126.35
	25.95	44.81	29.80	85.16	82.81	75.18	76.11	51.90	
10/82	67.42	29.54	6.27	20.27	4.78	2.21	3.33	0.88	82.36
	46.41	21.61	2.20	10.27	2.50	1.00	3.33	0.85	52.88
	-31.15	-26.86	-64.83	-50.58	-47.80	-54.98	-64.86	-2.84	-35.79
	21.67	30.81	35.09	29.58	65.69	51.13	68.77	137.50	22.54
11/82	33.19	23.24	3.18	7.90	2.87	1.75	3.15	0.54	53.41
	56.35	25.27	5.02	18.01	6.68	1.82	3.15	1.33	54.19
	69.76	8.71	57.86	127.97	132.75	4.00	33.81	147.22	1.46
	46.88	43.89	73.27	91.14	117.77	68.00	77.14	277.78	37.63
12/82	42.40	32.76	7.30	12.60	5.43	1.94	6.27	0.68	70.32
	37.48	24.67	5.22	8.75	3.09	1.12	6.27	0.93	51.11
	-11.62	-24.69	-28.42	-30.56	-43.09	-42.27	-49.52	37.50	-27.33
	31.84	23.84	28.88	39.05	52.85	54.64	33.81	126.47	23.83
1/83	27.94	31.26	11.64	12.08	7.20	2.05	10.39	0.51	39.99
	28.61	29.94	6.21	7.33	3.30	0.99	10.39	0.82	58.35
	2.40	-4.21	-46.61	-39.28	-57.92	-51.46	-69.30	60.78	45.91
	54.01	30.87	19.50	55.30	45.28	56.59	22.71	264.71	48.34

Table 13 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
2/83	89.42	70.30	13.95	33.12	6.69	2.12	12.56	0.66	47.91
	18.41	25.51	6.33	6.25	4.14	1.29	12.56	0.76	35.16
	-79.41	-63.71	-54.59	-81.11	-38.04	-39.15	-70.70	15.15	-26.61
	17.94	15.31	17.13	23.34	52.17	57.55	19.90	250.00	43.56
3/83	18.09	18.17	14.02	4.22	7.38	4.38	13.64	1.51	27.41
	27.71	32.77	7.92	7.97	4.28	1.04	13.64	0.45	44.37
	53.18	80.32	-43.47	88.98	-41.94	-76.26	-67.89	-70.53	61.88
	90.44	61.20	17.33	191.47	48.37	28.31	18.70	115.89	78.04
4/83	27.83	19.85	6.11	9.24	5.15	2.88	6.39	0.85	36.26
	42.01	25.82	4.74	15.27	5.29	1.40	6.39	0.58	42.33
	50.43	30.05	-22.42	65.21	2.82	-51.56	-30.75	-31.76	16.73
	50.02	42.12	34.70	58.87	57.86	37.85	34.27	118.82	48.35
5/83	59.19	26.91	3.06	28.43	11.56	3.48	2.80	1.08	49.53
	42.34	19.59	5.55	12.71	5.07	1.70	2.80	0.49	44.06
	-28.47	-27.20	81.37	-55.39	-56.14	-51.01	31.61	-54.63	-11.04
	26.56	38.61	76.80	25.91	29.50	34.48	87.50	143.52	41.11
6/83	140.95	37.89	5.95	42.59	10.18	2.53	1.53	1.85	157.53
	53.29	24.44	4.18	15.01	4.29	1.32	1.53	0.59	59.54
	-62.20	-35.50	-15.56	-64.76	-57.86	-47.83	16.34	-67.84	-62.20
	9.58	20.61	41.62	11.55	28.19	41.90	138.56	46.49	10.64
7/83	72.29	28.56	5.85	21.55	8.47	2.17	2.30	1.64	70.64
	115.09	32.06	4.06	34.64	6.31	1.47	2.30	3.91	117.06
	59.21	12.32	-30.60	60.74	-25.50	-32.26	-63.70	138.72	65.71
	20.21	31.86	37.61	18.54	37.07	52.07	99.57	73.78	26.27

Table 13 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
8/83	64.22	21.16	6.79	15.11	8.98	1.31	1.84	1.90	87.99
	53.34	24.43	7.20	18.84	8.70	1.92	1.84	1.99	41.88
	-16.94	15.45	5.96	24.69	-3.06	46.56	-67.93	4.47	-52.40
	14.98	50.85	35.20	51.16	38.86	93.13	135.87	86.84	23.72
9/83	39.97	17.80	2.29	14.49	6.80	1.43	1.89	0.59	49.62
	76.43	29.75	2.88	20.57	4.95	1.22	1.89	1.56	80.77
	91.23	67.16	25.76	41.93	-27.21	-15.03	-69.84	165.25	62.78
	34.95	46.97	92.58	37.54	43.82	76.22	115.87	171.19	35.33
10/83	27.36	16.34	3.54	7.64	5.34	1.21	1.77	0.47	24.20
	35.62	15.24	3.10	9.70	4.51	1.49	1.77	1.45	39.44
	27.85	-6.70	-12.43	27.03	-15.54	23.14	28.53	207.45	63.00
	54.16	59.06	64.12	37.43	61.05	95.87	133.33	287.23	79.88
11/83	13.26	13.01	1.14	2.60	2.63	0.83	2.20	0.62	23.03
	37.83	18.50	3.77	9.11	6.57	2.58	2.20	5.30	44.31
	185.33	42.24	231.14	250.58	149.81	211.49	-13.64	754.84	92.38
	98.19	55.80	175.44	168.85	104.10	124.10	93.18	114.52	69.43
12/83	9.11	9.82	1.53	1.21	2.54	0.84	2.22	1.09	15.37
	22.86	15.46	2.23	5.54	0.96	0.46	2.22	0.78	38.42
	150.93	57.38	46.08	357.85	-62.20	-45.24	-64.41	-28.44	150.00
	155.10	87.07	139.87	464.46	118.90	130.95	100.00	97.15	115.74
1/84	53.84	74.90	7.74	15.40	10.27	4.03	9.38	0.75	78.01
	11.48	12.33	2.40	1.60	0.75	0.45	9.38	0.49	23.88
	-78.68	-83.53	-68.93	-89.61	-92.70	-88.71	-91.31	-34.67	-69.38
	28.90	13.62	30.10	46.75	31.91	29.53	25.91	200.00	25.77

Table 13 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
2/84	34.87	45.60	5.33	12.30	13.21	3.11	6.95	0.54	43.52
	21.07	35.59	3.99	6.96	1.87	0.42	6.95	0.38	48.69
	-39.58	-21.95	-25.05	-43.37	-85.84	-86.50	-84.46	-28.70	11.87
	38.72	17.13	38.65	40.00	21.73	34.08	30.50	159.26	38.51
3/84	38.90	29.21	5.31	12.05	7.78	3.21	8.19	1.16	33.07
	23.05	28.20	3.25	8.68	1.23	0.53	8.19	3.30	45.46
	-40.75	-3.47	-38.89	-27.97	-84.13	-83.49	-63.61	184.05	37.45
	36.32	29.27	40.30	46.64	38.83	34.27	27.11	91.38	53.79
4/84	60.34	26.68	8.06	16.48	20.84	4.07	5.74	1.97	40.22
	26.01	23.31	9.02	6.12	13.34	2.82	5.74	1.69	28.28
	-56.89	-12.63	11.91	-62.86	-35.96	-30.59	62.11	-14.21	-29.69
	25.79	38.23	28.91	43.69	16.22	29.24	42.33	76.14	49.98
5/84	91.84	45.93	4.89	32.43	28.89	6.58	2.04	5.79	71.10
	41.30	31.40	3.45	9.55	13.50	0.80	2.04	0.49	65.00
	-55.03	-31.64	-29.45	-70.55	-53.27	-87.84	-50.98	-91.54	-8.58
	14.18	15.81	40.90	13.54	9.52	15.65	100.49	12.26	22.49
6/84	85.67	40.52	15.85	25.86	31.83	11.12	10.11	7.33	47.39
	43.55	21.01	9.95	19.10	6.60	1.60	10.11	0.85	38.05
	-49.17	-48.15	-37.22	-26.14	-79.26	-85.61	-93.08	-88.47	-19.71
	16.87	22.01	13.75	23.09	9.74	10.07	22.35	15.83	38.62

Table 14

Rainfall Quality in µeq/l at Canada Lake Using the ROGO Model:
Actual, ROGO Estimate, Percent Deviation Error, Estimated Error

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
4/83	69.78	41.86	8.47	18.29	16.72	5.68	9.64	1.77	70.35
	52.12	18.17	2.88	10.03	3.96	1.23	9.64	0.75	49.30
	-25.31	-56.58	-65.94	-45.16	-76.32	-78.35	-78.89	-57.91	-29.93
	22.30	24.37	27.51	39.37	20.22	20.95	25.21	8.475	28.57
5/83	40.75	22.22	9.96	12.09	7.98	3.89	9.38	0.62	44.98
	106.88	33.72	3.39	26.87	7.58	2.07	9.38	1.66	73.09
	162.28	51.76	-65.96	122.15	-5.01	-46.79	-84.33	167.74	62.49
	33.13	35.15	20.68	40.69	35.96	27.25	22.60	138.71	37.26
6/83	83.44	40.77	4.86	28.99	11.74	3.19	4.74	1.30	78.31
	46.42	21.61	2.20	10.27	2.50	1.00	4.47	0.85	52.88
	-44.37	-47.01	-54.63	-64.56	-78.75	-68.81	-75.32	-16.99	-32.47
	17.51	22.32	47.25	21.21	16.75	35.42	48.31	117.48	23.70
7/83	81.71	15.50	3.36	35.19	12.71	3.33	2.69	1.16	59.73
	56.35	25.27	5.02	18.01	6.68	1.82	2.69	1.33	54.19
	-31.04	-0.92	49.40	-48.82	-47.44	-45.35	56.69	15.09	-9.28
	19.04	40.00	69.35	20.46	26.59	35.74	90.33	129.31	33.65
8/83	82.34	33.38	10.85	23.24	18.60	4.38	4.63	1.82	68.28]
	37.48	24.67	5.22	8.75	3.09	1.12	4.63	0.93	51.11
	-54.49	-26.09	-51.84	-62.35	-83.39	-74.43	-31.64	-48-63	-25.15
	16.40	23.40	18.99	21.17	15.43	24.20	45.79	47.25	24.55
9/83	89.75	27.62	7.83	19.54	10.47	1.19	1.79	3.16	322.28
	28.61	29.94	6.21	7.33	3.03	0.99	1.79	0.82	58.35
	-58.12	8.41	-20.63	-62.46	-71.06	-16.39	78.21	-74.05	-81.89
	16.81	34.94	28.99	34.19	31.24	97.48	131.84	41.72	6.00

Table 14 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
10/83	55.67	20.30	4.15	16.10	6.52	1.88	3.41	0.50	82.23
	18.41	25.51	6.33	6.25	4.14	1.29	3.41	0.76	35.16
	-66.93	25.69	52.65	-61.15	-36.43	-31.38	7.92	52.00	-57.24
	28.81	53.00	57.59	48.01	53.53	64.89	73.31	330.00	25.38
11/83	38.96	20.84	8.23	10.23	7.15	4.23	7.64	2.14	29.90
	27.71	32.77	7.92	7.97	4.28	1.04	7.64	0.45	44.37
	-28.88	57.22	-3.71	-22.04	-40.07	-75.41	-42.67	-79.21	48.39
	41.99	53.36	29.53	78.98	49.93	29.31	33.38	81.78	71.54
12/83									
	42.86	33.06	3.32	10.16	6.34	3.44	5.20	2.48	56.42
	42.01	25.82	4.74	15.27	5.29	1.40	5.20	0.58	42.33
	-1.97	-21.90	42.77	50.25	-16.48	-59.45	-14.90	-76.61	-24.98
	32.59	25.29	63.86	53.54	47.00	31.69	42.12	40.73	31.07
1/84	19.63	19.49	3.32	3.80	4.52	2.13	4.00	0.59	29.89
	42.34	19.59	5.55	12.71	5.07	1.70	4.00	0.49	44.06
	115.69	0.51	67.17	234.34	12.17	-19.95	-7.88	-16.95	47.41
	80.08	53.31	70.78	194.21	75.44	56.34	61.25	262.71	68.12
2/84	30.22	47.39	7.21	12.17	5.37	2.58	6.24	0.46	57.26
	53.29	24.44	4.18	15.01	4.29	1.32	6.24	0.59	59.54
	76.32	-48.43	-42.02	23.34	-20.11	-48.84	-71.47	29.35	3.98
	44.67	16.48	28.57	40.43	53.45	41.09	33.97	186.96	29.27
3/84	45.38	44.14	5.90	17.96	8.62	3.24	5.14	0.62	63.54
	115.09	32.08	4.06	34.64	6.31	1.47	5.14	3.91	117.06
	153.61	-27.32	-31.19	92.87	-26.80	-54.63	-83.75	531.45	84.23
	32.19	20.62	37.29	34.24	36.43	34.88	44.55	195.16	29.21

Table 14 (continued)

	SO_4	NO_3	Cl	NH_4	Ca	Mg	Na	K	H
4/84	25.35	30.79	4.67	7.81	7.48	5.14	4.08	0.72	35.74
	53.34	24.43	7.20	18.84	8.70	1.92	4.08	1.99	41.88
	110.41	-20.66	54.07	141.07	16.38	-62.65	-85.54	175.69	17.18
	63.27	34.95	51.18	98.98	46.66	23.74	61.27	229.17	58.39
5/84	40.13	29.18	3.70	10.34	9.89	3.83	2.25	0.71	43.96
	76.43	29.75	2.88	20.57	4.95	1.22	2.25	1.56	80.77
	90.47	1.97	-22.16	98.89	-49.95	-68.28	-74.67	120.42	83.74
	34.81	28.65	57.30	52.61	30.13	28.46	97.33	142.25	39.88
6/84	37.82	26.55	2.87	15.64	12.17	2.95	1.50	1.34	45.11
	35.62	15.24	3.10	9.70	4.51	1.49	1.50	1.45	39.44
	-5.82	-42.58	8.01	-37.95	-62.94	-49.49	51.67	7.84	-12.56
	39.90	36.35	79.09	42.71	26.79	39.32	157.33	100.75	42.85

were within bounds. For H^+, the OSAWD model gave 66%, within the probable error limit. $SO_4^=$ showed the worst fit with 58% in bounds for the OSAWD model and 71% for the ROGO model. The worst agreement was at the Canada Lake site where only 40% of the OSAWD estimates for NO_3^- fell within bounds, the ROGO model again showed better agreement, with 53% in bounds. The H^+ ion model estimates were in bounds 40% and 47% for OSAWD and ROGO respectively while SO_4 model estimates were in bounds 13% and 20%. Both Paul A. Smith and Clear Lake showed similar agreement with Clear Lake showing slightly better agreement with $NO_3^=$ and H^+ 52% and 56% for the two models at Paul A. Smith vs. 69% and 65% for the models at Clear Lake for $NO_3^=$; and 56% and 56% for both models at Paul A. Smith vs. 52% and 65% for both models at Clear Lake. It should be noted here that the OSAWD model for $NO_3^=$ at Clear Lake was one of only two times that the OSAWD model exceeded the ROGO model for any of the major ions. Paul A. Smith and Clear Lake deviated the most on $SO_4^=$, with Paul A. Smith's OSAWD model estimate 39% in bounds at the ROGO model 35% in bounds. The Clear Lake model was 52% in bounds for the OSAWD model and 65% in bounds for the ROGO model.

It is interesting and disappointing to note that my model, which uses virtual sources based on $SO_4^=$ ions shows the poorest agreement with these. Would this same phenomenon hold true for the other major ions? The observation that the ROGO model fits somewhat better than the OSAWD model suggests that 347 km is too far between points to use the Gaussian plume methods or that a better method of calculating standard deviation in the x and y directions is necessary.

The fit of either model correlates with the distance from the imaginary line running from Ithaca to Whiteface Mountain, N.Y. (as

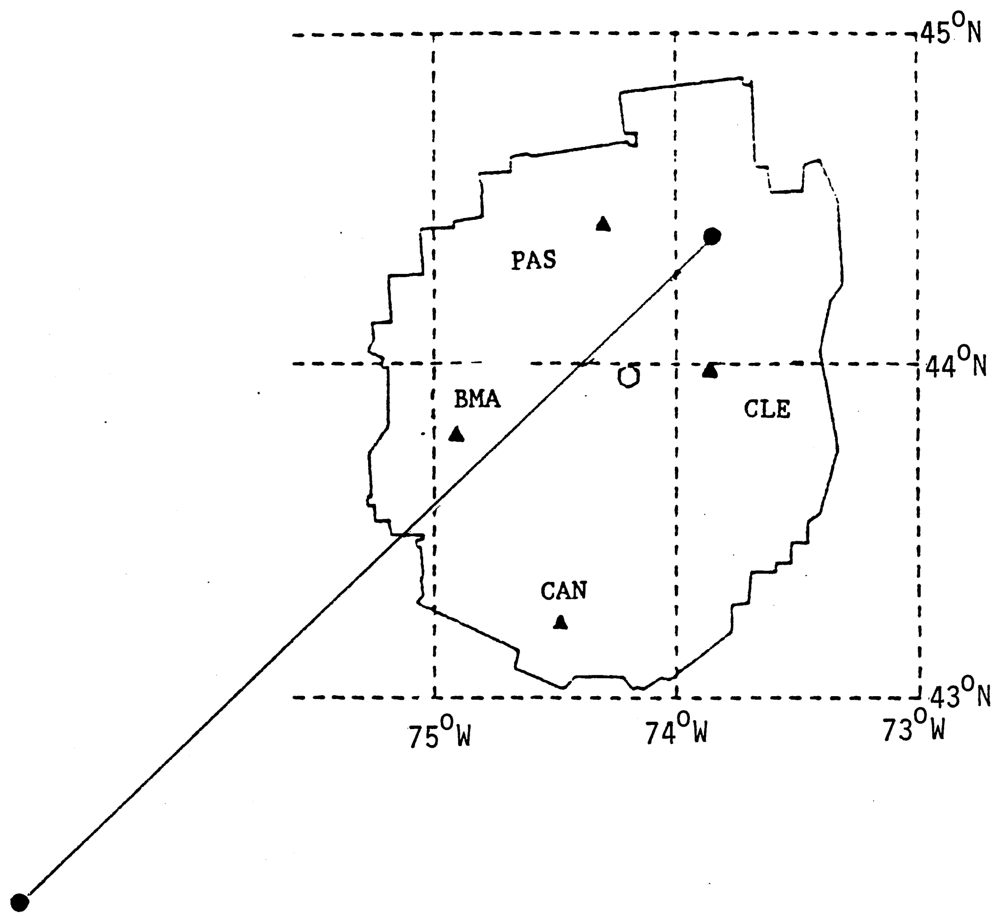
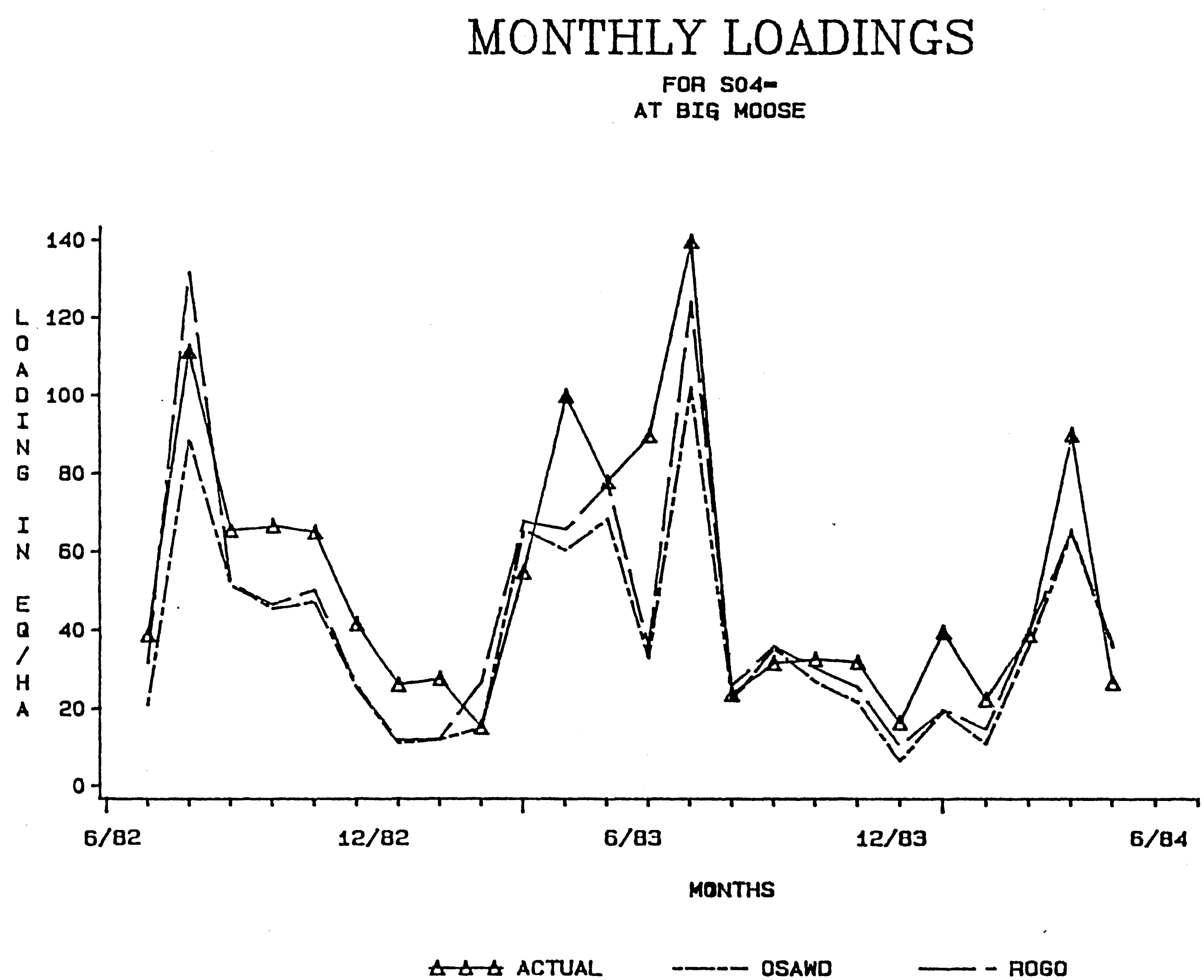


Figure 1 Quality Station Locations
MAP3S Sites (dots), RILWAS Quality Sites (triangles), and NADP HWL (hexagon)
Adapted from Garrity (33)

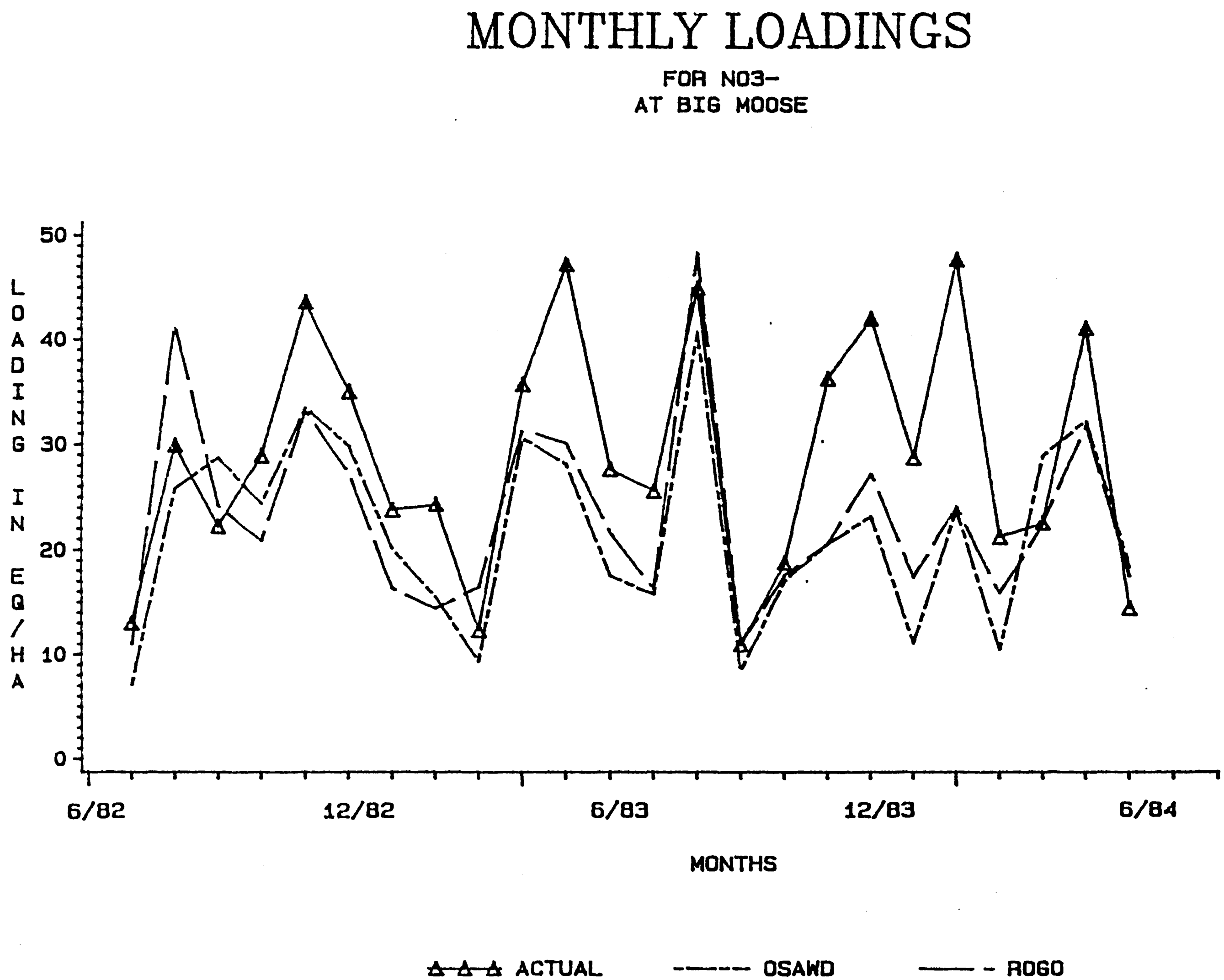
shown in Figure 1). Big Moose is the closest and shows the best agreement and Canada Lake is the furthermost and shows the poorest agreement while Paul A. Smith and Clear Lake are approximately the same distance and show similar agreement (although Paul A. Smith is slightly closer). This does not seem as if it should be a significant factor considering the distance from the Adirondacks to the Ohio Valley, a distance according to Galvan et al. (32) of over 1,000 km. It must also be noted that the OSAWD model, unlike the ROGO model, takes the distance from the imaginary line into account, and as we have seen, the ROGO model consistently out performs the OSAWD model.

Loadings for the three major ions ($NO_3^{=}$, $SO_4^{=}$ and H^{+}) using both the OSAWD and ROGO models were calculated using the definition of loading and are shown as Figures 2-13.



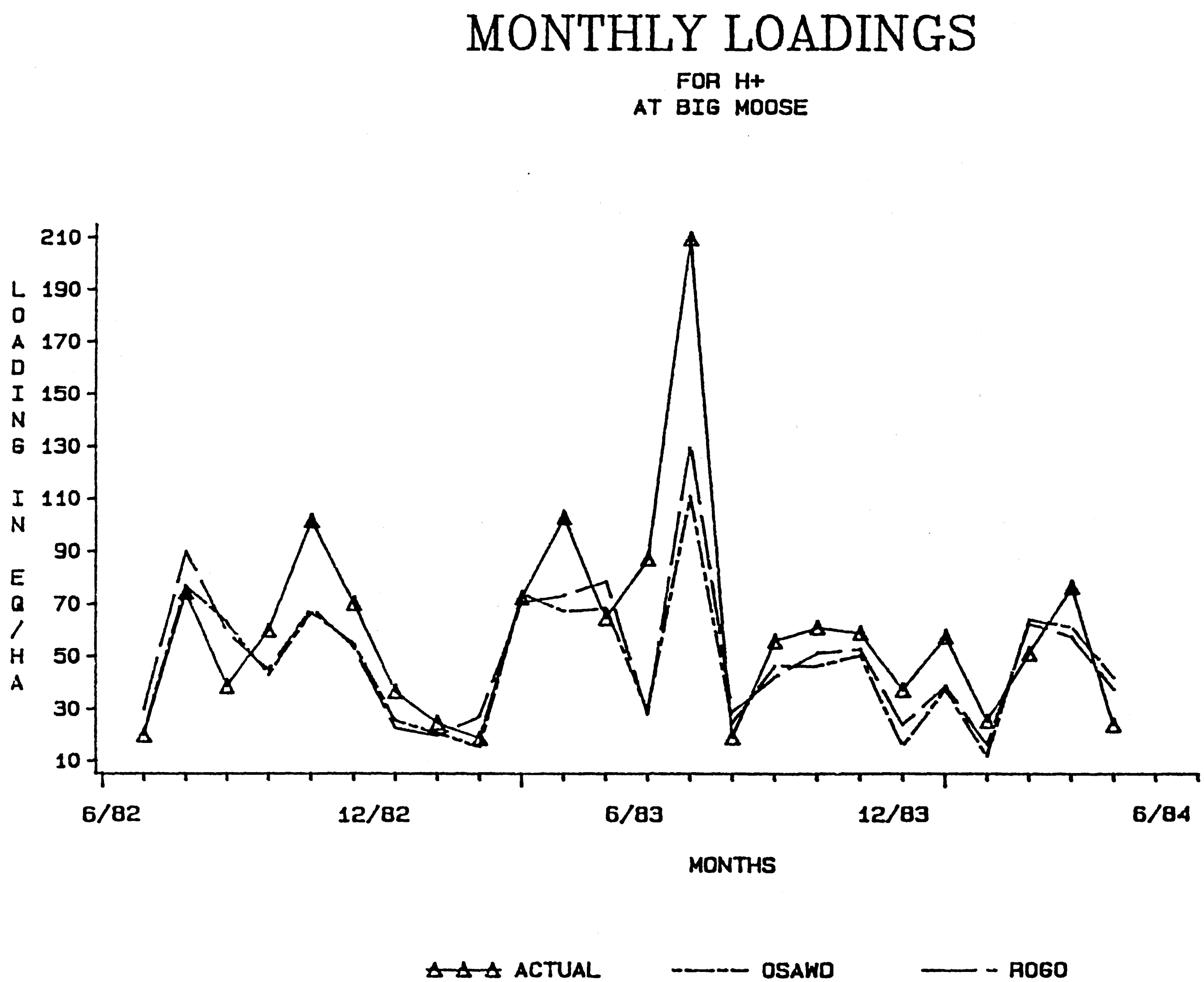
MONTHLY LOADINGS
FOR SO4=
AT BIG MOOSE
LOADING IN EQ/HA
140
120
100
80
60
40
20
0
6/82
12/82
6/83
12/83
6/84
MONTHS
ACTUAL
OSAWD
ROGO

Figure 2



MONTHLY LOADINGS
FOR NO3-
AT BIG MOOSE
LOADING IN EQ/HA
0
10
20
30
40
50
6/82
12/82
6/83
12/83
6/84
MONTHS
ACTUAL
OSAWD
ROGO

Figure 3


MONTHLY LOADINGS
FOR H+
AT BIG MOOSE
LOADINGS IN EQ/HA
210
190
170
150
130
110
90
70
50
30
10
6/82
12/82
6/83
12/83
6/84
MONTHS
ACTUAL
OSAWD
ROGO
Figure 4

MONTHLY LOADINGS

FOR SO4=
AT CLEAR LAKE

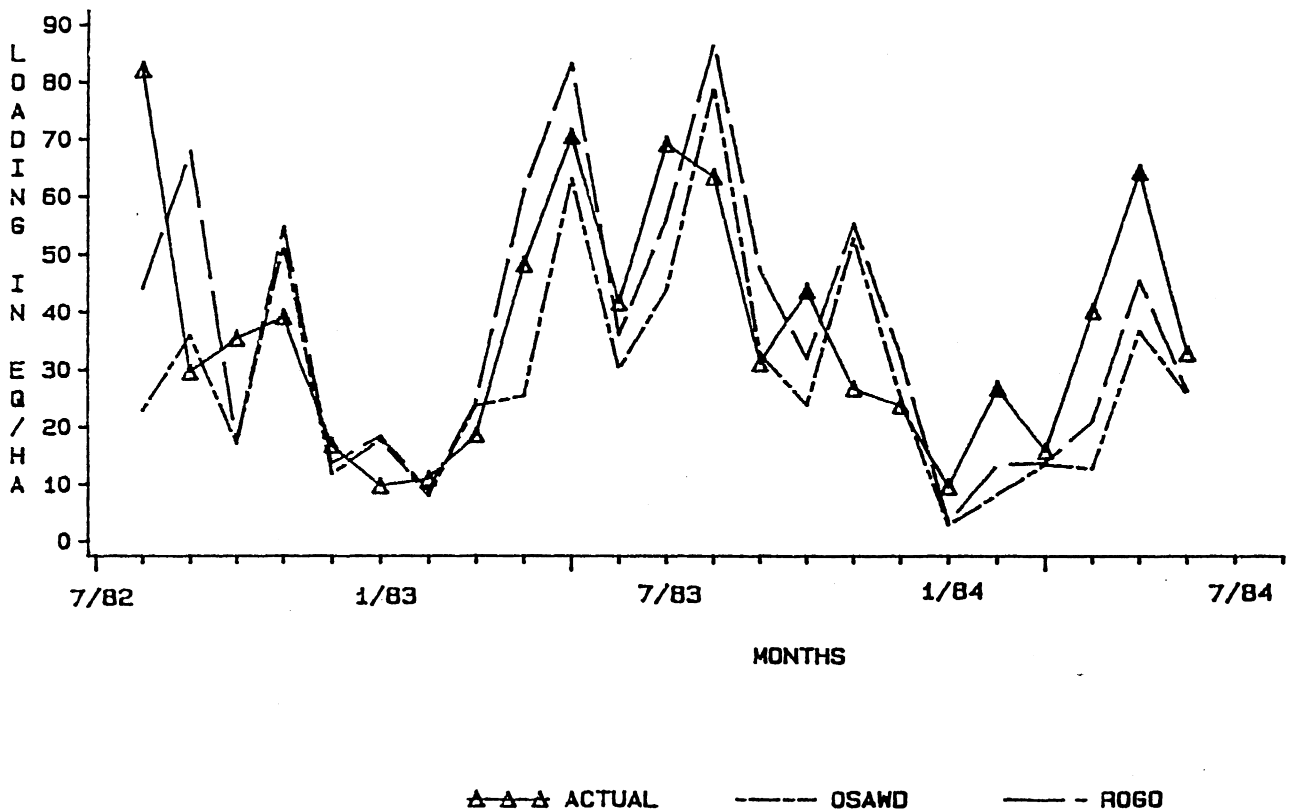


Figure 5

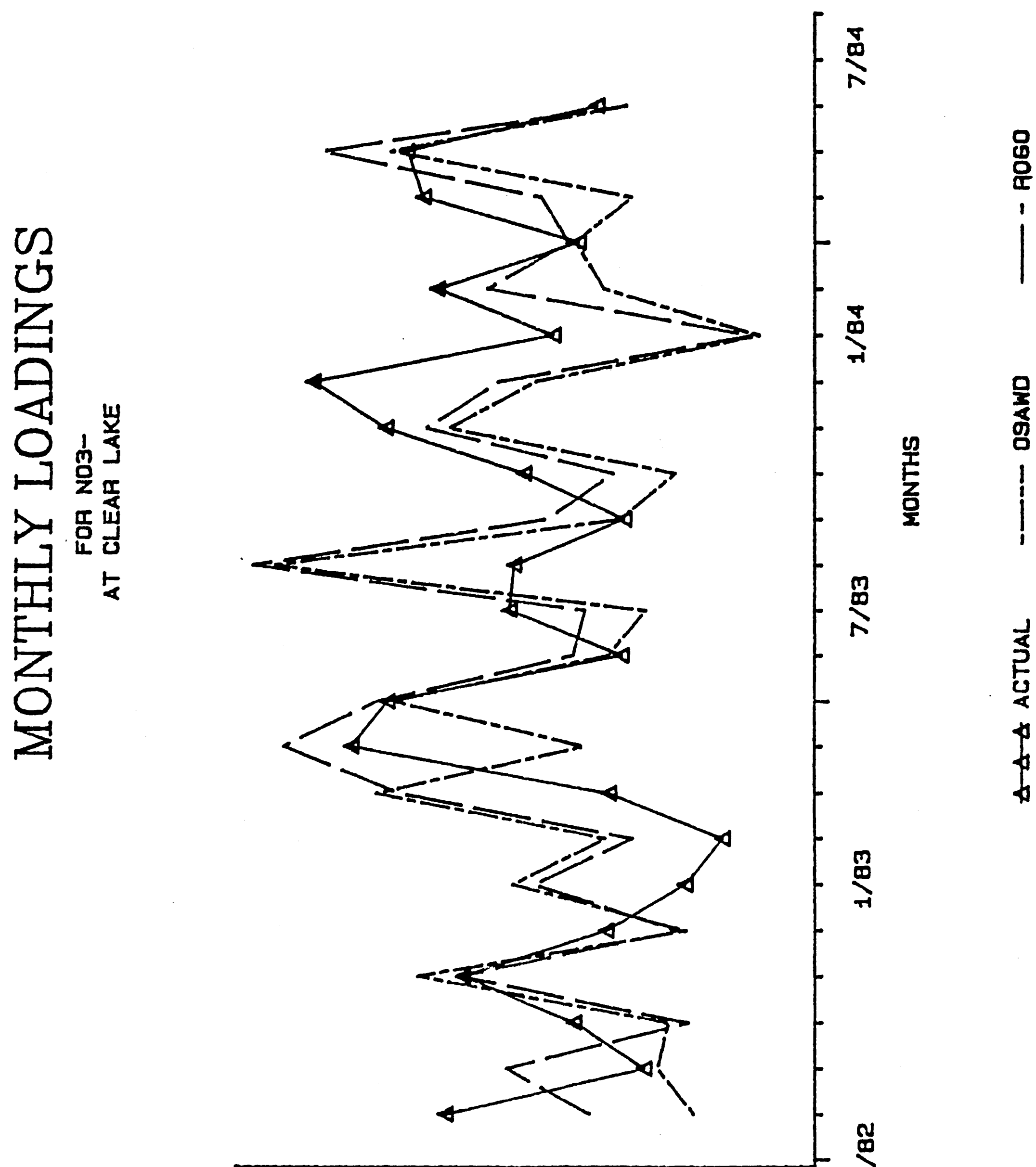

MONTHLY LOADINGS
FOR NO3-
AT CLEAR LAKE
LOADING IN EQ/HA
40
30
20
10
0
7/82
1/83
7/83
1/84
7/84
MONTHS
ACTUAL
OSAWD
RQGO

Figure 6

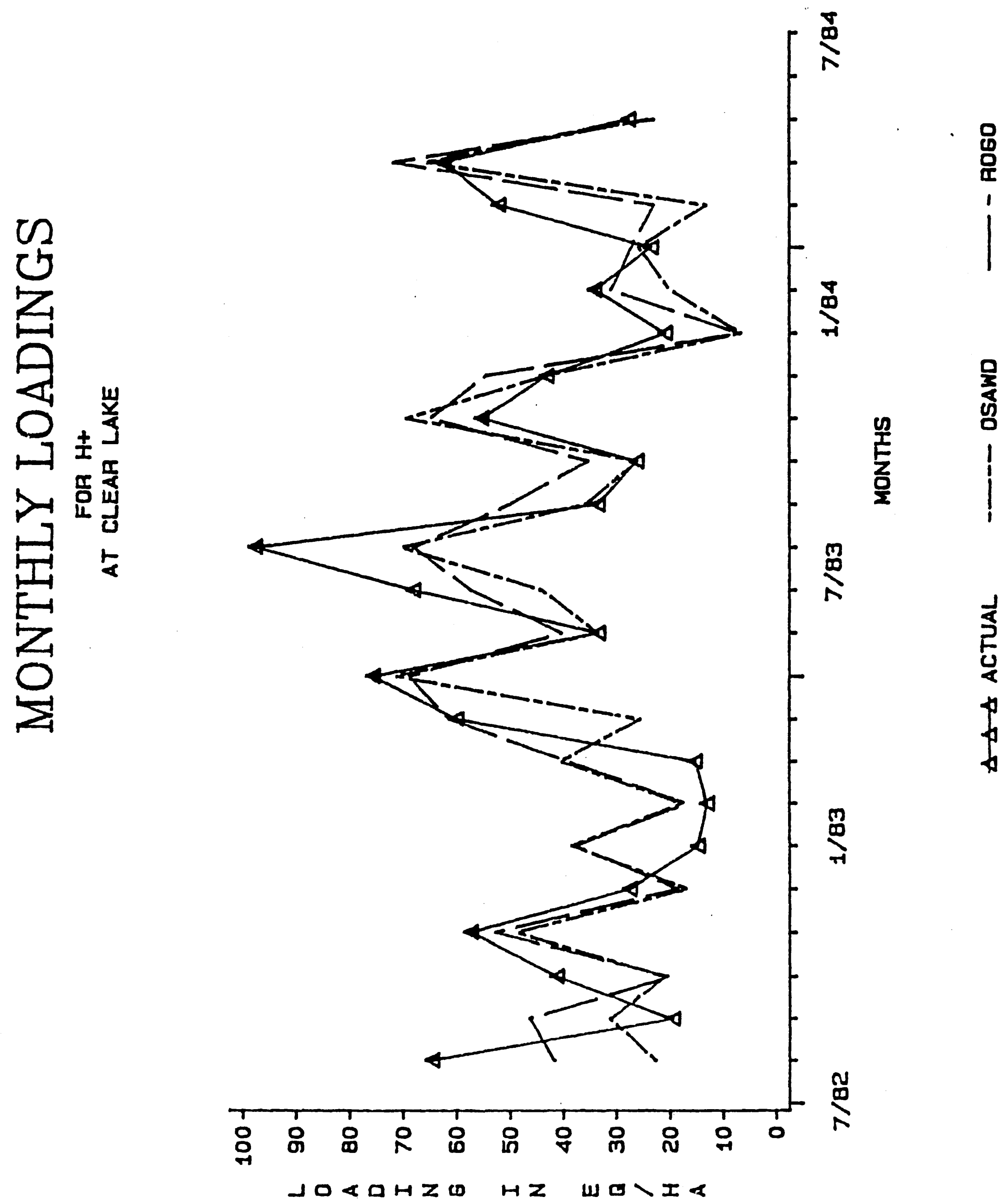

MONTHLY LOADINGS
FOR H+
AT CLEAR LAKE
LOADING IN EQ/HA
0
10
20
30
40
50
60
70
80
90
100
7/82
1/83
7/83
1/84
7/84
MONTHS
ACTUAL
OSAWD
ROGO

Figure 7

MONTHLY LOADINGS

FOR SO4=
AT PAUL A SMITH

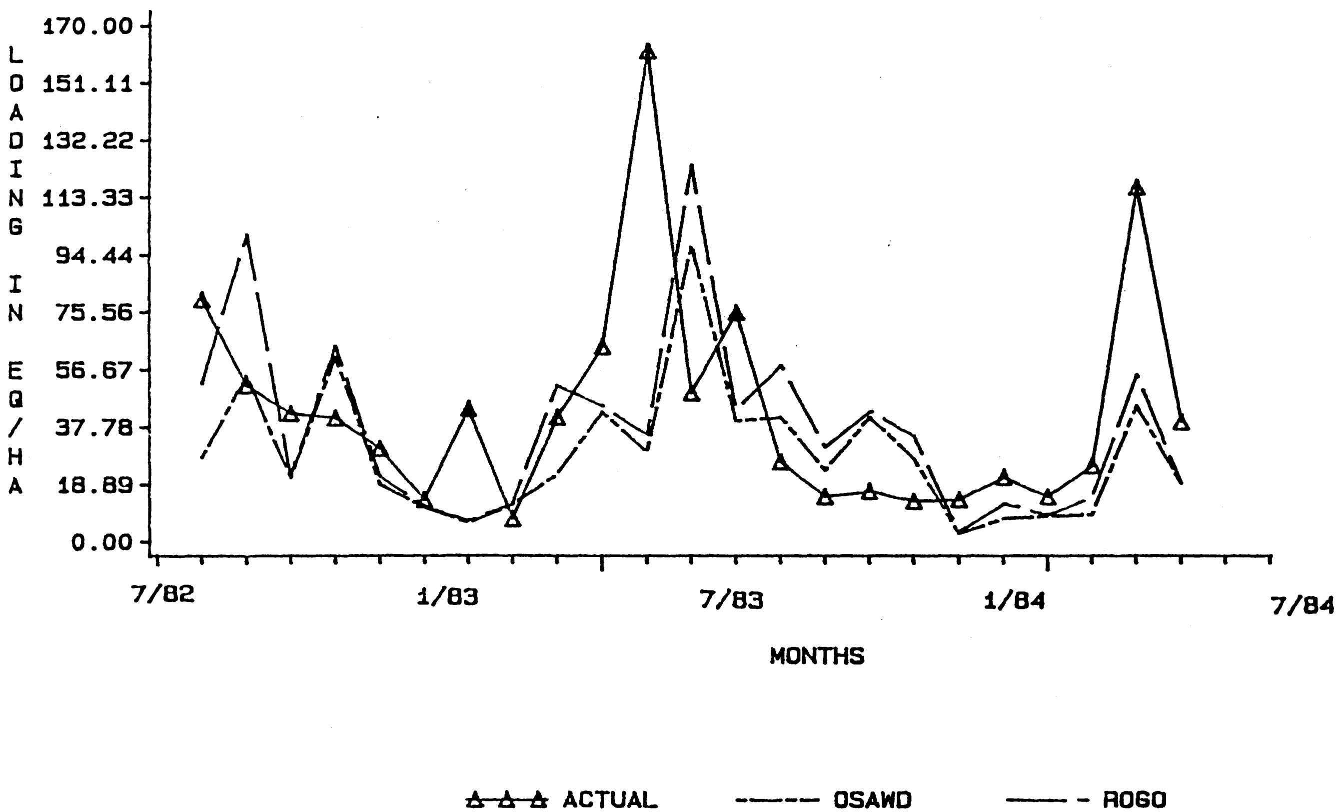


Figure 8

MONTHLY LOADINGS

FOR NO3-
AT PAUL A SMITH

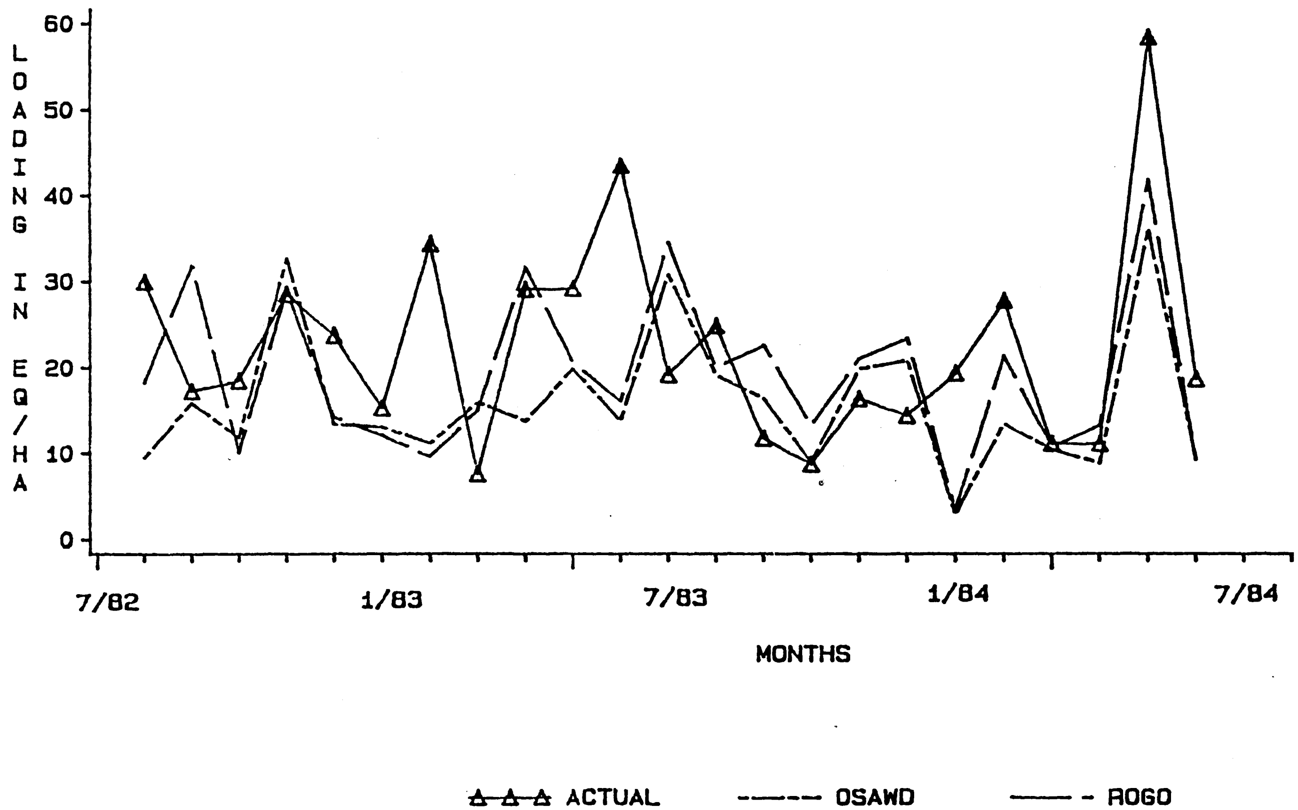


Figure 9

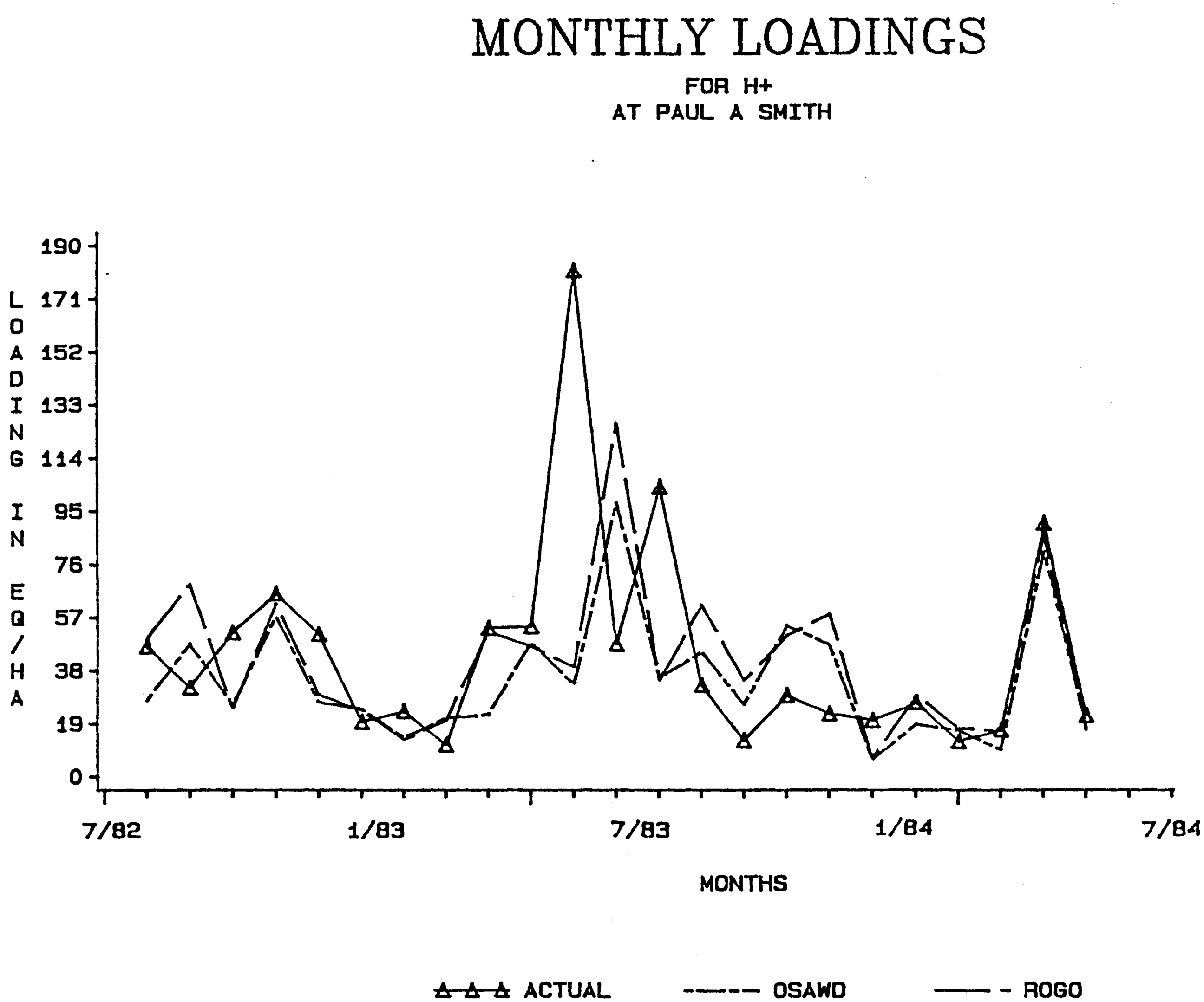

MONTHLY LOADINGS
FOR H+
AT PAUL A SMITH
LOADING IN EQ/HA
190
171
152
133
114
95
76
57
38
19
0
7/82
1/83
7/83
1/84
7/84
MONTHS
ACTUAL
OSAWD
ROGO

Figure 10

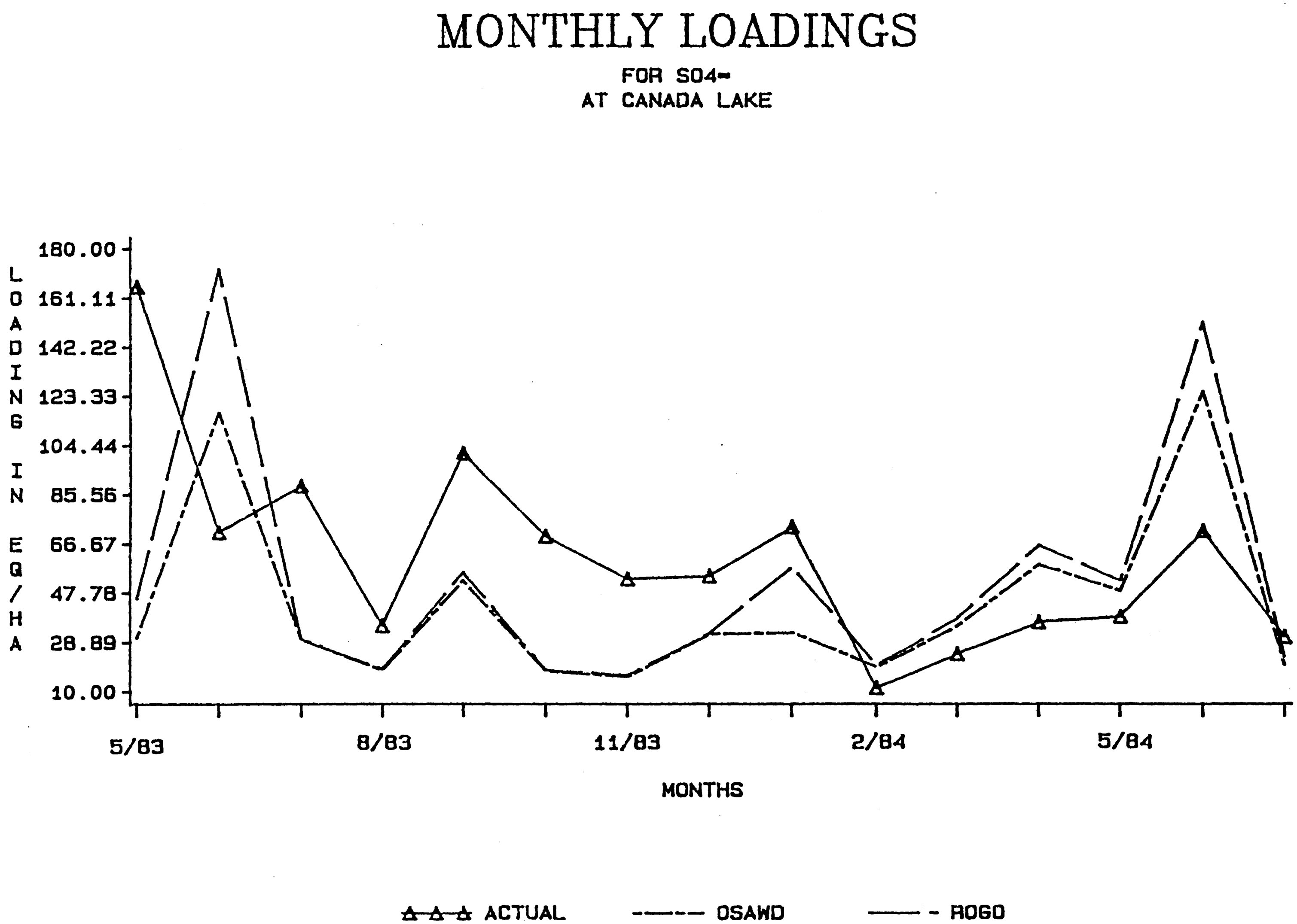

MONTHLY LOADINGS
FOR SO4=
AT CANADA LAKE
LOADINGS IN EQ/HA
180.00
161.11
142.22
123.33
104.44
85.56
66.67
47.78
28.89
10.00
5/83
8/83
11/83
2/84
5/84
MONTHS
ACTUAL
OSAWD
ROGO

Figure 11

MONTHLY LOADINGS

FOR NO3-
AT CANADA LAKE

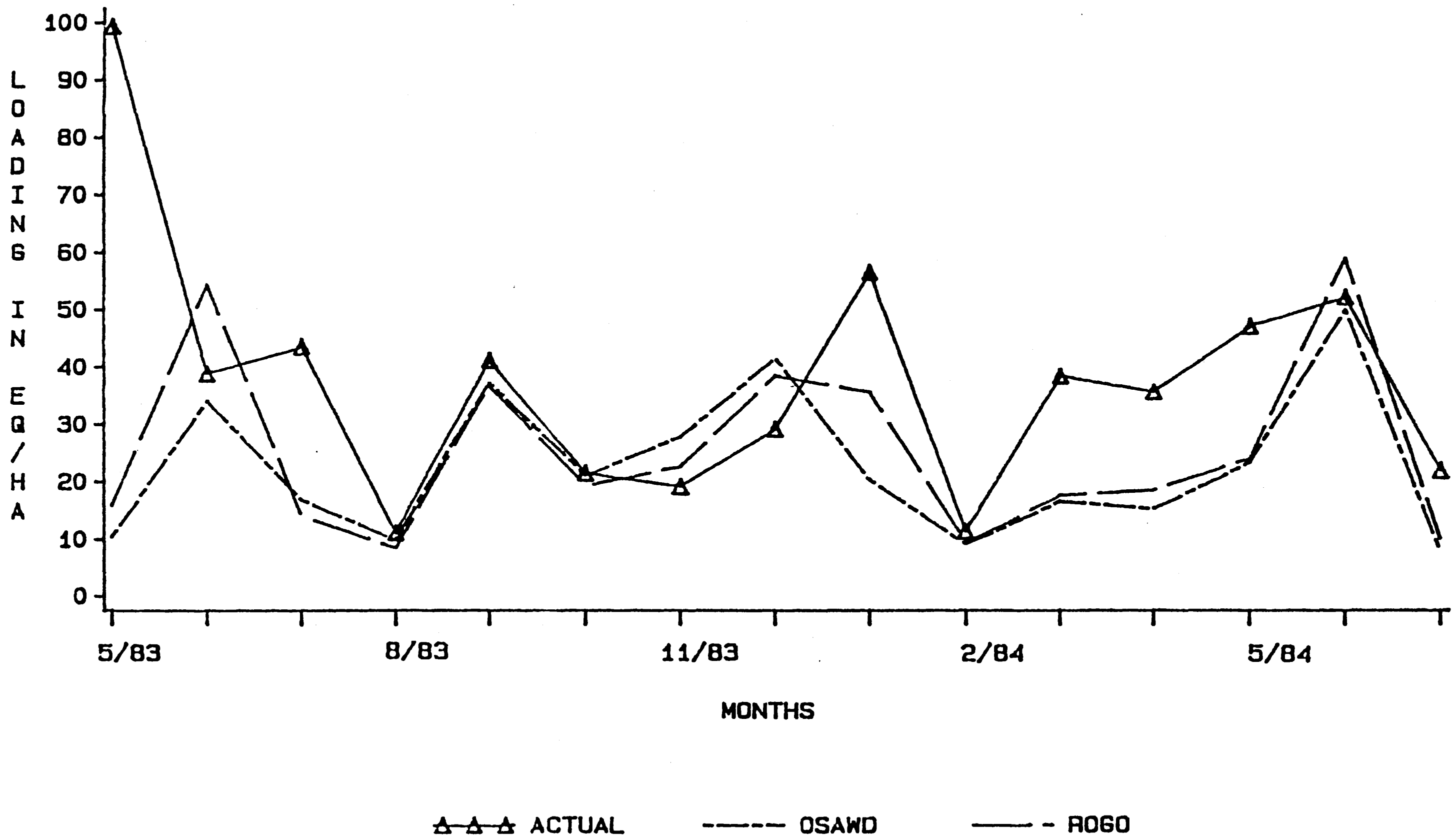


Figure 12

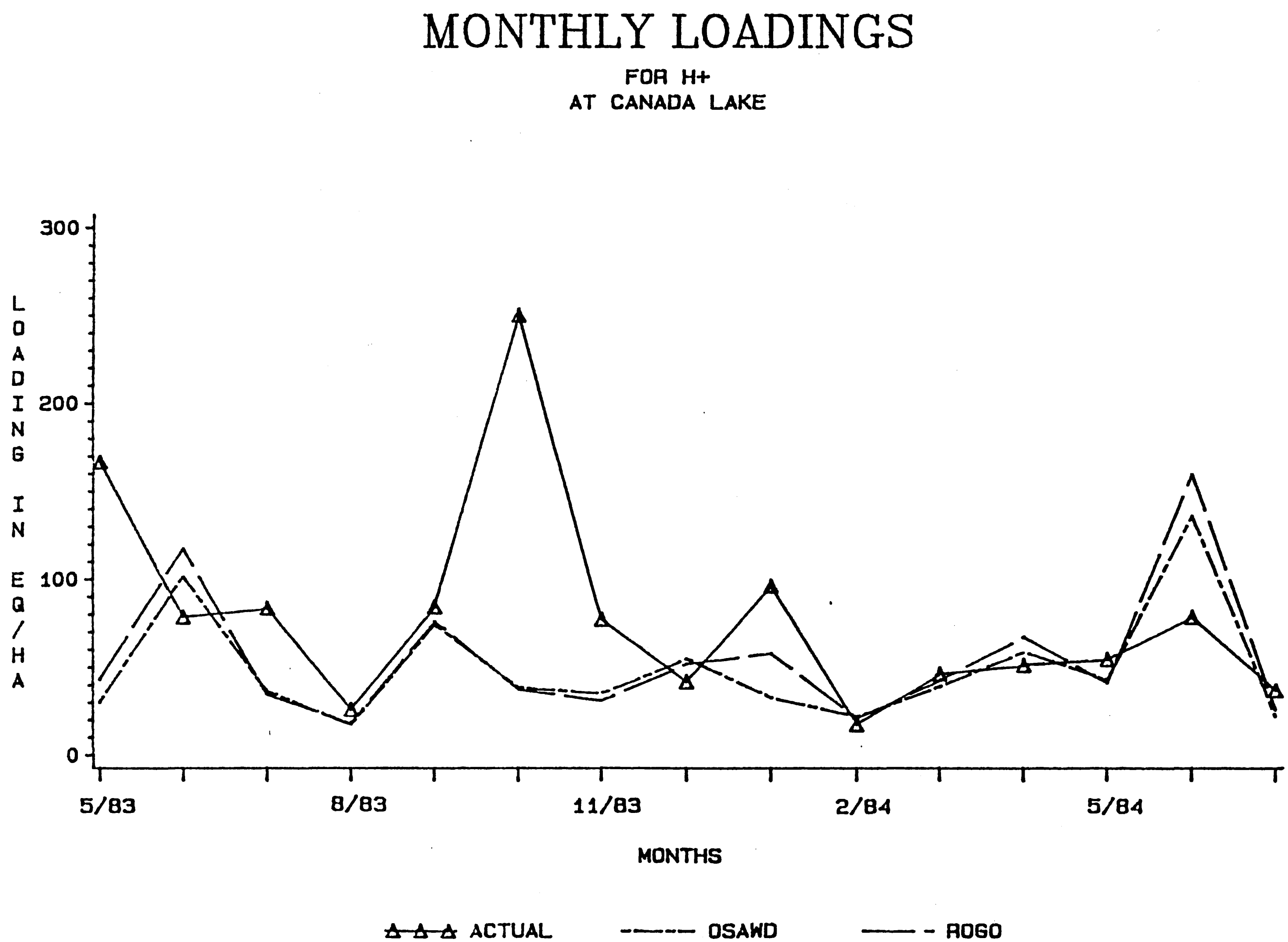

MONTHLY LOADINGS
FOR H+
AT CANADA LAKE
LOADING IN EQ/HA
300
200
100
0
5/83
8/83
11/83
2/84
5/84
MONTHS
ACTUAL
OSAWD
ROGO

Figure 13

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The corrected ROGO rainfall model provided rainfall estimates within the estimated error bounds for 63% of the points modeled. Because the ROGO model uses a Linsley/Theissen method for estimation, and the Linsley/Theissen method is the most widely used and reproducible method for estimating rainfall, I may accept 63% of points within the estimated error bounds as representative of any natural system.

Both the ROGO quality model and the OSAWD model were essentially no different in predicting the quality at each of the four locations in the park. Using the 63% criteria outlined in the preceding paragraph we see that both models show good fits at Big Moose, Clear Lake and Whiteface Mountain, but fit poorly at Canada Lake. Since Canada Lake is slightly closer to Ithaca, N.Y. than Big Moose, orographic effects must be more pronounced there.

It has been noted that there appears to be a correlation between the distance from the imaginary line running from Ithaca to Whiteface Mountain, but this is most likely purely coincidental.

Although the OSAWD model was specifically designed to fit $SO_4^{=}$, this ion had the poorest fit of the three major ions which I compared. The fit of the model to each individual ion is only influenced by the scavenging ratios, storm type, season, and possibly orographic effects, none of which I studied.

Both the ROGO model and the OSAWD model showed a consistent negative bias. Therefore, the positive bias which would be expected from DePena's work (32) was not evident. Rogowski (6) noted that the Ithaca, N.Y. MAP3S site provided an upper bound for the qualities at the RILWAS sites. This suggests that the Whiteface Mountain site has a strong negative bias, which in turn created a bias in the results of both models.

Before any improvements can be made in the OSAWD model to improve its efficiency, an orographic study of the four sites needs to be undertaken to provide information on the slope, aspect, surface roughness and Obukhov stability parameter to correct the model. A better fit is needed for the diffusion/dispersion parameters, possibly by using the Huntington NADP and UAPSP site #21 along with the MAP3S sites to develop a better model than the Wark and Warner (35) model which was not meant for use over such great distances.

The Whiteface Mountain MAP3S site should be resited to eliminate the negative bias in the models.

CHAPTER VI

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APPENDIX A

COMPUTER MODELS

```
C THIS IS THE ROGOA PROGRAM. IT IS PART OF THE ROGO WET
C LOADING MODEL FOR THE ADIRONDACK PARK OF NEW YORK
C STATE,WRITTEN BY DONALD ROGOWSKI AT RENSSELAER POLYTECH
C AND ADAPTED FOR USE ON OKLAHOMA STATE UNIVERSITY'S HARRIS
C 800 COMPUTER BY MARK SPRINGER.
C
C INPUTS
C
C 101 LATITUDE AND LONGITUDE OF SITES (43 00' TO 45 00' BY
C   72 55' TO 75 35')
C 102=PRECIPITATION QUANTITY AT THE SITES
C
C OUTPUTS
C
C 103=UNFILLED AND FILLED QUANTITY MATRICES
C 104=NEAREST NEIGHBOR TECHNIQUE ERROR ANALYSIS
C 108=ORIGIONAL UNFILLED QUANTITY MATRIX
C 110=INPUT TO ROGOB
C
C THE PRECIPITATION MATRIX IS DEVELOPED FROM NOAA
C PRECIPITATION QUANITY DATA.  ONE TIME PERIOD AT A TIME
C CAN BE PROCESSED FOR EACH RUN, I.E. ONE MONTH.
C
C RAIN-A MATRIX THAT CONTAINS THE CALCULATED RAINFALL.
C N-A MATRIX THAT CONTAINS THE NUMBER OF NOAA SITES THAT
C ARE LOCATED IN EACH SQUARE OF THE MATRIX.
C TEMP-A MATRIX THAT CONTAINS THE INTERMEDIATE MATRIX.
C RAINO-A MATRIX THAT CONTAINS THE ORIGINAL UNFILLED
C MATRIX.
C LATD-AN ARRAY CONTAINING THE LATITUDE DEGREES.
C LATM-AND ARRAY CONTAINING THE LATITUDE MINUTES.
C LONGD-AN ARRAY CONTAINING THE LONGITUDE DEGREES.
C LONGM-AN ARRAY CONTAINING THE LONGITUDE MINUTES.
C LONG-AN ARRAY CONTAINING THE X MATRIX COORDINATE.
C LAT-AN ARRAY CONTAINING THE Y MATRIX COORDINATE.
C
      REAL LATD,LATM,LONGD,LONGM,LAT,LONG,N
      COMMON RAIN(24,24), N(24,24)
      COMMON TEMP(24,24), RAINO(24,24)
      COMMON LATD(67), LATM(67), LONGD(67), LONGM(67)
      COMMON LAT(67), LONG(67),D(67)
      COMMON CONMAX
C THIS LOOP IS PERFORMED 67 TIMES SINCE FOR THE PROGRAM
C AS WRITTEN 67 SITES ARE USED.  THE LATITUDE AND
C LONGITUDE OF THE SITES ARE READ AND CONVERTED TO
C MATRIX COORDINATES.
      OPEN (UNIT=101,FILE='SPATIAL')
      OPEN (UNIT=102,FILE='NOAA')
      OPEN (UNIT=103,FILE='MATRIX')
      OPEN (UNIT=105,FILE='BORDER')
      OPEN (UNIT=104,FILE='ERROR')
```

```
      OPEN (UNIT=108,FILE='ORIGN')
      OPEN (UNIT=110,FILE='RAIN')
      OPEN (UNIT=113,FILE='MISTAK')
      DO 20 I = 1, 67
        READ (101,*) LATD(I), LATM(I), LONGD(I), LONGM(I)
        LAT(I) = 3.4 + 13.3 * ((LATD(I) + (LATM(I)/60.)) -
     1  42.)
        LONG(I) = 3.9 + 9.7 * (77. - (LONGD(I) + (LONGM(I)/
     1  60.)))
   20 CONTINUE
C  THE RAINFALL AT EACH SITE IS READ AT 67 TOTAL SITES,
C  36 INTERIOR SITES, AND 31 BORDER SITES. EACH RAINFALL
C  AMOUNT IS THEN CONVERTED FROM ENGLISH UNITS TO METRIC
C  UNITS.
      READ (102,32) (D(I),I=1,36)
   32 FORMAT(36(1X,F5.2))
      READ (105,42) (D(I),I=37,67)
   42 FORMAT(31(1X,F5.2))
C  THE RAIN AND N MATRICES ARE INITIALIZED.
      DO 60 I = 2, 23
        DO 50 II = 2, 23
          RAIN(I,II) = -.10
          N(I,II) = 0.
   50   CONTINUE
   60 CONTINUE
C  THEN MAXIMUM PRECIPITATION IS INITIALIZED TO 0.
      CONMAX = 0.
C  THIS LOOP IS PERFORMED FOR EACH SITE.
      DO 100 I = 1, 67
C  IF D(I,K) IS LESS THAN ZERO THIS MEANS THAT A QUANTITY
C  IS NOT AVAILABLE FOR THIS SITE AND THE NEXT SITE
C  SHOULD BE CHECKED.
        IF (D(I) .LT. 0.) GO TO 100
C  DETERMINE THE MAXIMUM RAINFALL, CONMAX.
        IF (CONMAX .LT. D(I))CONMAX=D(I)
C  IFLAG1 AND IFLAG2 ARE TWO FLAGS USED TO DETERMINE IF A
C  SITE IS ON THE BORDER OF TWO OR FOUR MATRIX SQUARES.
C  WHEN SET TO ZERO, THE SITE IS NOT ON A BORDER.
        IFLAG1 = 0
        IFLAG2 = 0
C  THIS STEP DETERMINES WHICH SQUARE IN THE X DIRECTION
C  THE SITE IS LOCATED IN.  IF IT IS ON THE BORDER IFLAG1
C  IS SET TO 1. THE PROGRAM THEN DETERMINES WHICH SQUARE
C  IN THE Y DIRECTION THE SITE IS LOCATED IN.  IF IT IS
C  ON THE BORDER IFLAG2 IS SET TO 1.  THE SQUARE SIZE IS
C  SET AT 7.5 BY 7.5 MINUTES BASED ON THE SIZE OF A MINUTE
C  OF LONGITUDE.
        III = IFIX((LATD(I) - 43.)*11.)
        IF (LATM(I) .EQ. 0.) IFLAG1 = 1
        IF (LATM(I) .EQ. 60./11.) IFLAG1 = 1
        IF (LATM(I) .EQ. 120./11.) IFLAG1 = 1
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      IF (LATM(I) .EQ. 180./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 240./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 300./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 360./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 420./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 480./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 540./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 600./11.) IFLAG1 = 1
      IF (LATM(I) .EQ. 660./11.) IFLAG1 = 1
      IF (LATM(I) .GE. 0. .AND. LATM(I) .LT. 60./11.)
     1 III = III + 1
      IF (LATM(I) .GE. 60./11. .AND. LATM(I) .LT. 120./11.)
     1 III = III + 2
      IF (LATM(I) .GE. 120./11. .AND. LATM(I) .LT. 180./11.)
     1 III = III + 3
      IF (LATM(I) .GE. 180./11. .AND. LATM(I) .LT. 240./11.)
     1 III = III + 4
      IF (LATM(I) .GE. 240./11. .AND. LATM(I) .LT. 300./11.)
     1 III = III + 5
      IF (LATM(I) .GE. 300./11. .AND. LATM(I) .LT. 360./11.)
     1 III = III + 6
      IF (LATM(I) .GE. 360./11. .AND. LATM(I) .LT. 420./11.)
     1 III = III + 7
      IF (LATM(I) .GE. 420./11. .AND. LATM(I) .LT. 480./11.)
     1 III = III + 8
      IF (LATM(I) .GE. 480./11. .AND. LATM(I) .LT. 540./11.)
     1 III = III + 9
      IF (LATM(I) .GE. 540./11. .AND. LATM(I) .LT. 600./11.)
     1 III = III + 10
      IF (LATM(I) .GE. 600./11. .AND. LATM(I) .LT. 660./11.)
     1 III = III + 11
      III = 24 - III
      II = IFIX((LONGD(I) - 72.)*8.)
      IF (LONGM(I) .EQ. 0.) IFLAG2 = 1
      IF (LONGM(I) .EQ. 7.5) IFLAG2 = 1
      IF (LONGM(I) .EQ. 15.) IFLAG2 = 1
      IF (LONGM(I) .EQ. 22.5) IFLAG2 = 1
      IF (LONGM(I) .EQ. 30.) IFLAG2 = 1
      IF (LONGM(I) .EQ. 37.5) IFLAG2 = 1
      IF (LONGM(I) .EQ. 45.) IFLAG2 = 1
      IF (LONGM(I) .EQ. 52.5) IFLAG2 = 1
      IF (LONGM(I) .GE. 7.5 .AND. LONGM(I) .LT. 15.)
     1 II = II + 1
      IF (LONGM(I) .GE. 15. .AND. LONGM(I) .LT. 22.5)
     1 II = II + 2
      IF (LONGM(I) .GE. 22.5 .AND. LONGM(I) .LT. 30.)
     1 II = II + 3
      IF (LONGM(I) .GE. 30. .AND. LONGM(I) .LT. 37.5)
     1 II = II + 4
      IF (LONGM(I) .GE. 37.5 .AND. LONGM(I) .LT. 45.)
     1 II = II + 5
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```
            IF (LONGM(I) .GE. 45 .AND. LONGM(I) .LT. 52.5)
         1  II = II + 6
            IF (LONGM(I) .GE. 52.5 .AND. LONGM(I) .LT. 60.)
         1  II = II + 7
            II = 30 - II
C  ADD THE QUANTITY TO THE APPROIATE SQUARE AND NOTE THIS
C  IN MATRIX N.
            IF (RAIN(III,II) .EQ. - .10) RAIN(III,II) = 0.
            RAIN(III,II) = RAIN(III,II) + D(I)
            N(III,II) = N(III,II) + 1.
C  IF THE SITE IS NOT ON THE BORDER GOTO THE NEXT SITE.
            IF ((IFLAG1 .EQ. 0) .AND. (IFLAG2 .EQ. 0))
        1      GO TO 100
C  DOES THE SITE BORDER IN THE Y DIRECTION?
            IF (IFLAG1 .EQ. 0) GO TO 70
            J = III + 1
            IF (RAIN(J,II) .EQ. - .10) RAIN(J,II) = 0.
            RAIN(J,II) = RAIN(J,II) + D(I)
            N(J,II) = N(J,II) + 1.
C  DOES THE SITE BORDER IN THE X DIRECTION?
   70       IF (IFLAG2 .EQ. 0) GO TO 80
            J = II + 1
            IF (RAIN(III,J) .EQ. - .10) RAIN(III,J) = 0.
            RAIN(III,J) = RAIN(III,J) + D(I)
            N(III,J) = N(III,J) + 1.
C DOES THE SITE SIT AT THE INTERSECTION OF FOUR SQUARES?
   80       IF ((IFLAG1 .EQ. 1) .AND. (IFLAG2 .EQ. 1))
     1         GO TO 90
            GO TO 100
   90       III = III + 1
            II = II + 1
            IF (RAIN(III,II) .EQ. - .10) RAIN(III,II) = 0.
            RAIN(III,II) = RAIN(III,II) + D(I)
            N(III,II) = N(III,II) + 1.
  100 CONTINUE
C  CORRECT THE RAINFALL IN EACH SQUARE FOR THE NUMBER OF
C  SITES IN THE SQUARE.
          DO 120 I = 2, 23
            DO 110 II = 2, 23
              IF (N(I,II) .NE. 0.) RAIN(I,II) =
     1        RAIN(I,II)/N(I,II)
  110       CONTINUE
  120 CONTINUE
C  SET UP A BOUNDARY AROUND THE AREA OF INTEREST.
          DO 130 I = 1, 24
            RAIN(1,I) = -.2
            RAIN(24,I) = -.2
  130 CONTINUE
          DO 140 I = 2, 23
            RAIN(I,1) = -.2
            RAIN(I,24) = -.2
```

```
  140 CONTINUE
C  SET THE NUMBER OF MISSING BOXES EQUAL TO ZERO.
      MISSG = 0
      DO 160 I = 1, 24
C  THIS WRITE WILL OUTPUT THE ORIGINAL UNFILLED MATRIX.
        WRITE (108,450) (RAIN(I,IP),IP=1,24)
C  SET UP TEMP AND RAINO MATRICES.
        DO 150 II = 1, 24
          TEMP(I,II) = RAIN(I,II)
          RAINO(I,II) = RAIN(I,II)
C  DETERMINE HOW MANY SQUARES NEED TO BE FILLED.
          IF (RAIN(I,II) .EQ. - .10) MISSG = MISSG + 1
  150   CONTINUE
  160 CONTINUE
C  IF THE MATRIX IS COMPLETE SKIP THE MATRIX FILLING STEP.
      IF (MISSG .EQ. 0) GO TO 310
C  IFLAG3 SET EQUAL TO 0 IT INDICATES THAT AT LEAST ONE
C  SQUARE WAS FILLED AT THE CURRENT MISSING NEIGHBOR
C  REQUIREMENT.
      IFLAG3 = 0
C  MISSX IS THE CURRENT NUMBER OF MISSINIG NEAREST
C  NEIGHBORS IS ALLOWABLE WHEN CALCULATING THE VALUE FOR
C  A SQUARE.
      MISSX = 0
      IF (MISSG .EQ. 0) GO TO 310
  170 DO 270 I = 2, 23
        DO 260 II = 2, 23
C  DETERMINE IF THE CURRENT SQUARE IS FILLED OR NOT.
          IF (RAIN(I,II) .NE. - .10) GO TO 260
C  SET MISS, THE NUMBER OF MISSING NEAREST NEIGHBORS EQUAL
C  TO ZERO.
          MISS = 0
C  CHECK ALL EIGHT NEIGHBORS TO SEE HOW MANY ARE MISSING.
          J = I - 1
          JJ = II - 1
          IF (RAIN(J,JJ) .EQ. - .10) MISS = MISS + 1
          IF (RAIN(J,II) .EQ. - .10) MISS = MISS + 1
          JJ = II + 1
          IF (RAIN(J,JJ) .EQ. - .10) MISS = MISS + 1
          IF (RAIN(I,JJ) .EQ. - .10) MISS = MISS + 1
          JJ = II - 1
          IF (RAIN(I,JJ) .EQ. - .10) MISS = MISS + 1
          J = I + 1
          IF (RAIN(J,JJ) .EQ. - .10) MISS = MISS + 1
          IF (RAIN(J,II) .EQ. - .10) MISS = MISS + 1
          JJ = II + 1
          IF (RAIN(J,JJ) .EQ. - .10) MISS = MISS + 1
C  CHECK TO SEE IF THE NUMBER OF MISSING NEIGHBORS IS
C  ACCEPTABLE.  IF NOT CHECK THE NEXT SQUARE.  IF SO,
C  CALCULATE ITS VALUE.
          IF (MISS .NE. MISSX) GO TO 260
```

```
C  ADD UP ALL VALID NEIGHBORS AND THE NUMBER OF VALID
C  NEIGHBORS.
            J = I - 1
            JJ = II - 1
            DIV = 0.
            TOT = 0.
            IF (RAIN(J,JJ) .LT. 0.) GO TO 180
            TOT = RAIN(J,JJ)
            DIV = 1.
  180       IF (RAIN(J,II) .LT. 0.) GO TO 190
            TOT = TOT + RAIN(J,II)
            DIV = DIV + 1.
  190       JJ = II + 1
            IF (RAIN(J,JJ) .LT. 0.) GO TO 200
            TOT = TOT + RAIN(J,JJ)
            DIV = DIV + 1.
  200       IF (RAIN(I,JJ) .LT. 0.) GO TO 210
            TOT = TOT + RAIN(I,JJ)
            DIV = DIV + 1.
  210       JJ = II - 1
            IF (RAIN(I,JJ) .LT. 0.) GO TO 220
            TOT = TOT + RAIN(I,JJ)
            DIV = DIV + 1.
  220       J = I + 1
            IF (RAIN(J,JJ) .LT. 0.) GO TO 230
            TOT = TOT + RAIN(J,JJ)
            DIV = DIV + 1.
  230       IF (RAIN(J,II) .LT. 0.) GO TO 240
            TOT = TOT + RAIN(J,II)
            DIV = DIV + 1.
  240       JJ = II + 1
            IF (RAIN(J,JJ) .LT. 0.) GO TO 250
            TOT = TOT + RAIN(J,JJ)
            DIV = DIV + 1.
C  BECAUSE OF THE BORDERS, IT IS POSSIBLE TO HAVE AN
C  ACCEPTABLE NUMBER OF MISSING NEIGHBORS BUT NO VALUES
C  FROM WHICH TO DETERMINE A SQUARE VALUE.  IF THIS
C  SHOULD OCCUR PROCEED AS IF THE ARE AN UNACCEPTABLE
C  NUMBER OF MISSING NEIGHBORS.
  250       IF (DIV .EQ. 0.) GO TO 260
C  IF IT IS POSSIBLE TO GET A VALUE, STORE IT IN TEMP.
C  THIS WILL PREVENT US FROM WORKING WITH NEW VALUES UNTIL
C  THE PREVIOUS MATRIX HAS ALL POSSIBLE VALUES CALCULATED.
            TEMP(I,II) = TOT / DIV
C  REDUCE THE NUMBER OF MISSING SQUARES BY ONE.
            MISSG = MISSG - 1
C  SET FLAG3 EQUAL TO 1 SO THAT WE KNOW THAT WE WERE ABLE
C  TO CALCULATE AT LEAST ONE NEW SQUARE VALUE.
            IFLAG3 = 1
  260    CONTINUE
  270 CONTINUE
```

```
C  IF IT WAS NOT POSSIBLE TO OBTAIN A NEW VALUE AT THE
C  GIVEN LEVEL OF MISSING NEIGHBORS, INCREASE THE
C  ACCEPTABLE VALUE OF MISSING NEIGHBORS BY ONE AND NOW
C  TRY TO CALCULATE A NEW VALUE.
      IF (IFLAG3 .EQ. 1) GO TO 280
      MISSX = MISSX + 1
      GO TO 170
C  IF IT WAS POSSIBLE TO OBTAIN AT LEAST ONE NEW BOX VALUE
C  SET THE PERMENANT MATRIX EQUAL TO THE TEMPORARY MATIX.
  280 DO 300 I = 2, 23
        DO 290 II = 2, 23
          RAIN(I,II) = TEMP(I,II)
  290   CONTINUE
  300 CONTINUE
C  SINCE A NEW BOX VALUE WAS CALCULATED, LET'S SET THE
C  ACCEPTABLE NUMBER OF MISSING NEIGHBORS EQUAL TO ZERO.
      MISSX = 0
C  SET IFLAG3 EQUAL TO 0 AS BEFORE.
      IFLAG3 = 0
C  REPEAT THIS MATRIX FILLING PROCESS UNTIL ALL OF THE
C  SQUARES ARE FILLED.
      IF (MISSG .NE. 0) GO TO 170
C   NOW THAT THE MATRIX IS FILLED, LET'S SEE HOW GOOD THE
C   ORIGINAL MATRIX IS ESTIMATED FROM THE VALUES FOUND BY
C   THE NEAREST NEIGHBOR APPROACH, I.E. ERROR ANALYSIS.
  310 DO 430 I = 2, 23
        DO 420 II = 2, 23
          IF (RAINO(I,II) .GE. 0.) GO TO 320
          GO TO 420
  320     RQV = 0.
          RDN = 0.
          ID = I - 1
          IF (RAIN(ID,II) .LT. 0.) GO TO 330
          RQV = RQV + RAIN(ID,II)
          RDN = RDN + 1.
  330     IID = II + 1
          IF (RAIN(ID,IID) .LT. 0.) GO TO 340
          RQV = RQV + RAIN(ID,IID)
          RDN = RDN + 1.
  340     IF (RAIN(I,IID) .LT. 0.) GO TO 350
          RQV = RQV + RAIN(I,IID)
          RDN = RDN + 1.
  350     ID = I + 1
          IF (RAIN(ID,IID) .LT. 0.) GO TO 360
          RQV = RQV + RAIN(ID,IID)
          RDN = RDN + 1.
  360     IF (RAIN(ID,II) .LT. 0.) GO TO 370
          RQV = RQV + RAIN(ID,II)
          RDN = RDN + 1.
  370     IID = II - 1
          IF (RAIN(ID,IID) .LT. 0.) GO TO 380
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              RQV = RQV + RAIN(ID,IID)
              RDN = RDN + 1.
  380         IF (RAIN(I,IID) .LT. 0.) GO TO 390
              RQV = RQV + RAIN(I,IID)
              RDN = RDN + 1.
  390         ID = I - 1
              IF (RAIN(ID,IID) .LT. 0.) GO TO 400
              RQV = RQV + RAIN(ID,IID)
              RDN = RDN + 1.
C   RQV IS THE CALCULATED VALUE FOR THE LOCATION OF THE
C   ORIGINAL VALUE.
  400         RQV = RQV / RDN
C   RD IS THE DIFFERENCE BETWEEN THE ORIGINAL AND
C   CALCULATED VALUE.
              RD = RAINO(I,II) - RQV
              RE = -999.99
C RE IS THE PERCENT ERROR BASED ON THE ORIGINAL VALUE.
              IF (RAINO(I,II) .NE. 0.) RE = RD * 100. / RAINO(
     1        I,II)
C  THIS WRITE OUTPUTS THE ERROR ANALYSIS.
C             WRITE (104,410) I, II, RAINO(I,II), RQV, RD, RE
C 410         FORMAT (1X, 'I ', I2, '  II ', I2, ' K ',I2,'
C    1                   RO ',F5.2,'  RC ', F5.2, '  RD ', F6.2, '
C    2                   RE ',F7.2)
  420       CONTINUE
  430     CONTINUE
C
C  THIS WRITE OUTPUTS THE MAXIMUM QUANTITY.  IT IS USED BY
C  ROGOB.
          WRITE (110,440) (CONMAX)
  440     FORMAT (1X, F5.2)
          WRITE(3,441) RAIN(15,7),RAIN(12,16),RAIN(8,12),RAIN(22,10)
  441     FORMAT(4(2X,F5.2))
          DO 480 I = 1, 24
C  THIS WRITE OUTPUTS THE FINAL RAIN GRID.
            WRITE (103,450) (RAIN(I,IP),IP=1,24)
  450       FORMAT (24(1X,F4.2))
            DO 470 II = 1, 24
C  THIS WRITE OUTPUTS THE FINAL RAIN MATRIX FOR USE BY
C  ROGOB.
              WRITE (110,460) I,II,RAIN(I,II)
  460         FORMAT (1X,I2,1X,I2,1X, F5.2)
  470       CONTINUE
  480     CONTINUE
          CLOSE 101
          CLOSE 102
          CLOSE 103
          CLOSE 104
          CLOSE 105
          CLOSE 108
          CLOSE 110
```

```
C      THIS IS THE ANERR PROGRAM. IT ESTIMATES ERRORS IN THE
C      ROGO RAINFALL MODEL FOR THE ADIRONDACK PARK OF NEW YORK
C      STATE WRITTEN BY DONALD ROGOWSKI AT RENSSELAER POLYTECHNIC
C      INSTITUTE. THE ANERR PROGRAM WAS WRITTEN BY MARK SPRINGER
C      AT OKLAHOMA STATE UNIVERSITY.
C
C      INPUTS
C
C      101=THE ACTUAL RAINFALL RECORDED AT THE FOUR RILWAS QUALITY
C          MONITORING SITES
C      102= THE RAINFALL ESTIMATED BY THE ROGOA MODEL AT THE FOUR
C           RILWAS QUALITY MONITORING SITES
C
C      OUTPUT
C
C      103=THE ACTUAL RAINFALL,ESTIMATED RAINFALL,PERCENT DEVIATION,
C          AND ESTIMATED ERROR FOR EACH OF THE FOUR RILWAS QUALITY
C          MONITORING SITES
C
       REAL PE(24,4),EE(24,4),RAIN(24,4),EST(24,4)
       REAL ME,SE(24,4),CE(24,4),C,AREA,G,A(24,4)
       CHARACTER DAT(24)*5
       INTEGER I,II,S
       OPEN(UNIT=101,FILE='ARAIN')
       OPEN(UNIT=102,FILE='MRAIN')
       OPEN(UNIT=103,FILE='ANA1')
C      INITALIZE THE ERROR IN MEASUREMENT (ME),THE DISCRETIZATION
C      ERROR (C),AND THE GAGING RATIO (G).
       ME = 0.086
       C = SQRT(0.001836)+ 0.0459
       AREA = 260.2
       G = 260.2/67.
       DO 1 I=1,24
       READ(101,10) DAT(I),RAIN(I,1),RAIN(I,2),RAIN(I,3),RAIN(I,4),S
    10 FORMAT(1X,A5,1X,F5.2,1X,F5.2,1X,F5.2,1X,F5.2,1X,I1)
       READ(102,20) EST(I,1),EST(I,2),EST(I,3),EST(I,4)
    20 FORMAT(1X,F5.2,1X,F5.2,1X,F5.2,1X,F5.2)
C      CHECK TO SEE IF THE MONTH IS IN THE WINTER OR SUMMER. IF IT
C      IS A WINTER MONTH THE MEASUREMENT ERROR BECOMES 0.10922.
       IF(S .EQ. 1)THEN
       ME = 0.10922
       ELSE
       ME = 0.086
       ENDIF
C      CHECK TO SEE RAINFALL WAS RECORDED AT ALL SITES FOR 24 MONTHS
C      IF NOT MAKE THE RECORDED RAINFALL EQUAL TO THE ROGO ESTIMATE.
       DO 2 II=1,4
       IF(RAIN(I,II) .EQ. 00.00)THEN
       RAIN(I,II) = EST(I,II)
       ENDIF
C      CALCULATE THE PERCENT DEVIATION,THE SAMPLING ERROR (SE),
```

```
C     THE DISCRETIZATION ERROR AND THE TOTAL ESTIMATED ERROR.
      PE(I,II) = ((RAIN(I,II)-EST(I,II))/RAIN(I,II))*100.
      A(I,II) = (-1.3132+0.73*LOG(G)-0.56*LOG(AREA))
      SE(I,II) = EXP(A(I,II)+0.72*LOG(RAIN(I,II)))
      CE(I,II) = C/RAIN(I,II)
      EE(I,II) = (ME + SE(I,II) + CE(I,II))*100.
    2 CONTINUE
    1 CONTINUE
C     WRITE(103,30)
C  30 FORMAT('ERROR ANALYSIS BY SITES')
      WRITE(103,50)
   50 FORMAT(25X,'BMA')
      WRITE(103,60)
   60 FORMAT(4X,'DATE',6X,'ACT',6X,'EST',6X,'PERCENT',3X,'EST')
   70 FORMAT(14X,'RAIN',5X,'RAIN',5X,'ERROR',5X,'ERROR')
      WRITE(103,70)
      DO 3 I=1,24
C     CONVERT RAINFALL UNITS TO CM
      EST(I,1) = EST(I,1)*2.54
      RAIN(I,1) = RAIN(I,1)*2.54
      WRITE(103,40) DAT(I),RAIN(I,1),EST(I,1),PE(I,1),EE(I,1)
   40 FORMAT(/,4X,A5,3X,F6.2,3X,F6.2,4X,F7.2,4X,F6.2)
    3 CONTINUE
      WRITE(103,71)
   71 FORMAT(1H1)
      WRITE(103,90)
   90 FORMAT(25X,'CLE')
      WRITE(103,60)
      WRITE(103,70)
      DO 4 I=1,24
      EST(I,2) = EST(I,2)*2.54
      IF(RAIN(I,2) .EQ. 1111.)THEN
      EE(I,2) = 1000000.
      PE(I,2) = 1000000.
      ELSE
      ENDIF
      RAIN(I,2) = RAIN(I,2)*2.54
      WRITE(103,40) DAT(I),RAIN(I,2),EST(I,2),PE(I,2),EE(I,2)
    4 CONTINUE
      WRITE(103,71)
      WRITE(103,100)
  100 FORMAT(25X,'PAS')
      WRITE(103,60)
      WRITE(103,70)
      DO 5 I=1,24
      EST(I,3) = EST(I,3)*2.54
      IF(RAIN(I,3) .EQ. 1111.)THEN
      RAIN(I,3) = 10000000.
      EE(I,3) = 10000000.
      PE(I,3) = 10000000.
      ELSE
```

```
      ENDIF
      RAIN(I,3) = RAIN(I,3)*2.54
      WRITE(103,40) DAT(I),RAIN(I,3),EST(I,3),PE(I,3),EE(I,3)
    5 CONTINUE
      WRITE(103,71)
      WRITE(103,110)
  110 FORMAT(25X,'CAN')
      WRITE(103,60)
      WRITE(103,70)
      DO 6 I=1,24
      EST(I,4) = EST(I,4)*2.54
      IF(RAIN(I,4) .EQ. 1111.)THEN
      RAIN(I,4) = 10000000.
      EE(I,4) = 10000000.
      PE(I,4) = 10000000.
      ELSE
      ENDIF
      RAIN(I,4) = RAIN(I,4)*2.54
      WRITE(103,40) DAT(I),RAIN(I,4),EST(I,4),PE(I,4),EE(I,4)
    6 CONTINUE
      STOP
      END
```

```
C       THIS IS THE NORMAL PROGRAM. IT IS PART OF THE
C       OSAWD MODEL FOR THE ADIRONDACK PARK OF NEW YORK
C       STATE WRITTEN BY MARK SPRINGER AT OKLAHOMA STATE
C       UNIVERSITY.
C
C       THIS PROGRAM CALCULATES A GAUSSIAN FACTOR WHICH WHEN
C       MULTIPLIED BY THE IONIC COMPOSITION RECORDED AT ITHACA NEW
C       YORK GIVES THE OSAWD MODEL.
C
C       INPUTS
C
C       103=THE DISTANCE FROM ITHACA NEW YORK TO ONE OF THE EIGHT
C           QUALITY MONITORING SITES AND THE DISTANCE FROM THE SITE
C           TO A POINT NORMAL TO THAT SITE ON THE IMAGENARY LINE RUNNING
            FROM ITHACA TO WHITEFACE MTN. NEW YORK
C       110=THE LATITUDE AND LONGITUDE OF THE 4 RILWAS SITES,
C           THE UAPSP SITE #21, THE HUNTINGTON WILDLIFE NADP SITE,
C           AND THE MAP3S SITES AT ITHACA AND WHITEFACE MTN. NEW YORK
C       105=THE DISTANCE OF THE VIRTUAL SOURCE FROM ITHACA NEW YORK
C
C       OUTPUT
C
C       111=THE GAUSSIAN (NORMAL) FACTOR FOR EACH SITE
C
        REAL LATD(8),LATM(8),LONGD(8),LONGM(8)
        REAL LAT(8),LONG(8),DS(8),DVIR(24)
        REAL X(8),Y(8),FX(8,24),SGMY(8,24)
        REAL SGMZ(8,24),SGM(8,24),TDS(8,24)
        REAL E(8,24),Z(8),ZM(8),ISGMZ(24)
        REAL ISGMY(24),ISGM(24)
        OPEN (UNIT=103,FILE='XY')
        OPEN (UNIT=110,FILE='LOCAL')
        OPEN (UNIT=105,FILE='SOURCE')
        OPEN (UNIT=111,FILE='GAUSS')
C       READ IN THE NUMBER OF MONTHS DESIRED AND BEGIN
C       A LOOP TO CALCULATE GAUSSIAN FACTORS.
        WRITE(3,*) 'MONTHS=?'
        READ(3,*) MO
C       THIS LOOP IS PERFORMED 8 TIMES FOR EACH OF THE QUALITY MONITORING
C       STATIONS IN THE PARK. THE LATITUDE AND LONGITUDE ARE CONVERTED TO
C       DECIMAL VALUES.
        DO 10 I=1,8
        READ (110,20) LATD(I),LATM(I),LONGD(I),LONGM(I)
     20 FORMAT(1X,F2.0,1X,F2.0,2X,F2.0,1X,F2.0)
        LAT(I) = (LATD(I) + LATM(I)/60.)
        LONG(I) = (LONGD(I) + LONGM(I)/60.)
     10 CONTINUE
        CLOSE 110
C       READ IN THE DISTANCE FROM THE VIRTUAL SOURCE, THE DISTANCE
C       ALONG AN IMAGENARY LINE RUNNING FROM ITHACA TO WHITEFACE MTN.
C       AND THE DISTANCE NORMAL TO THE IMAGENARY LINE FOR EACH QUALITY
```

```
C     QUALITY MONITORING STATION.
      DO 30 J=1,MO
      READ(105,40) DVIR(J)
   40 FORMAT(1X,F6.0)
   30 CONTINUE
      DO 50 I=1,4
      READ(103,60) DS(I),Z(I)
   60 FORMAT(1X,F6.2,2X,F6.2)
   50 CONTINUE
C     THIS LOOP CALCULATES THE DIFFUSION/DISPERSION COEFFICIENTS
C     FOR ITHACA NEW YORK USING WARK AND WARNER'S METHOD FOR CLASS
C     'D' STABILITY.
      DO 70 J=1,MO
      ISGMY(J) = 68.*DVIR(J)**0.894
      ISGMZ(J) = (44.5*DVIR(J)**0.516)-13.00
      ISGM(J) = ISGMY(J)*ISGMZ(J)
   70 CONTINUE
      DO 80 I=1,4
C     THIS LOOP CALCULATES THE DIFFUSION/DISPERSION COEFFICIENTS,
C     AND THE GAUSSIAN FACTOR FOR EACH OF THE EIGHT QUALITY MONITORING
C     SITES FOR EACH MONTH.
      DO 90 J=1,MO
      TDS(I,J) = DS(I) + DVIR(J)
      SGMY(I,J) = 68.*(TDS(I,J)**0.894)
      SGMZ(I,J) = 44.5*(TDS(I,J)**0.516)-13.00
      SGM(I,J) = SGMY(I,J)*SGMZ(I,J)
      E(I,J) = EXP(-0.5*(Z(I)**2/SGMY(I,J)**2))
      FX(I,J) = (ISGM(J)/SGM(I,J))*(E(I,J))
   90 CONTINUE
   80 CONTINUE
      DO 99 J=1,MO
      WRITE (111,100) (FX(I,J),I=1,4)
  100 FORMAT(4(1X,F7.5))
   99 CONTINUE
      STOP
      END
```

```
C     THIS IS THE IONIC SUBROUTINE OF THE EQCON PROGRAM.
C     IT IS PART OF THE OSAWD MODEL FOR THE ADIRONDACK PARK
C     OF NEW YORK STATE WRITTEN BY MARK SPRINGER AT OKLAHOMA
C     STATE UNIVERSITY.
C
C     THIS MODEL ESTIMATES THE IONIC CONCENTRATIONS AT ONE OF
C     THE FOUR RILWAS QUALITY MONITORING SITES USING THE OSAWD
C     MODEL.
C
C     INPUTS
C
C     101=THE GAUSSIAN (NORMAL) FACTORS CALCULATED IN THE NORMAL
C         PROGRAM
C     102=THE IONIC CONCENTRATIONS RECORDED AT ITHACA NEW YORK
C
C     OUTPUT
C
C     103=THE IONIC CONCENTRATION ESTIMATED AT ONE OF THE FOUR
C         RILWAS QUALITY MONITORING SITES USING THE OSAWD MODEL
C
      SUBROUTINE IONIC
      REAL X(4),Y(4),GAUSS(4,24),ISO4(24)
      REAL INO3(24),ICL(24),INH4(24),ICA(24)
      REAL IMG(24),INA(24),IK(24),IH(24)
      REAL SO4(4,24),NO3(4,24),CL(4,24),NH4(4,24)
      REAL CA(4,24),MG(4,24),NA(4,24),K(4,24),H(4,24)
      INTEGER I,II
      OPEN (UNIT=101,FILE='GAUSS')
      OPEN (UNIT=102,FILE='ITH')
      OPEN (UNIT=103,FILE='FINAL')
C     THEESE TWO LOOPS READ IN THE RECORDED IONIC CONCETRATIONS AT THE ITHACA
C     MONTIORING SITE AND THE ESTIMATED GAUSSIAN FACTOR FOR EACH OF THE FOUR
C     RILWAS SITES FOR THE 24 MONTH PERIOD OF INTREST.
      DO 10 II=1,24
      READ(102,30) ISO4(II),INO3(II),ICL(II),INH4(II)
     1,ICA(II),IMG(II),INA(II),IK(II),IH(II)
 30   FORMAT(9(1X,F6.2))
 10   CONTINUE
      DO 20 II=1,24
      READ(101,50) GAUSS(1,II),GAUSS(2,II),GAUSS(3,II),GAUSS(4,II)
 50   FORMAT(4(1X,F7.5))
 20   CONTINUE
C     THE USER CHOOSES A SITE FROM THE FOUR RILWAS SITES AND THE ESTIMATED
C     IONIC CONCENTRATION IS CALCULATED.
      WRITE(3,*) 'ENTER SITE ID NUMBER'
      READ(3,*) I
      DO 40 II=1,24
      SO4(I,II) = ISC4(II)*GAUSS(I,II)
      NO3(I,II) = INC3(II)*GAUSS(I,II)
      CL(I,II) = ICL(II)*GAUSS(I,II)
      NH4(I,II) = INH4(II)*GAUSS(I,II)
```

```
      CA(I,II) = ICA(II)*GAUSS(I,II)
      MG(I,II) = IMG(II)*GAUSS(I,II)
      NA(I,II) = INA(II)*GAUSS(I,II)
      K(I,II) = IK(II)*GAUSS(I,II)
      H(I,II) = IH(II)*GAUSS(I,II)
 40   CONTINUE
      DO 60 II=1,24
      WRITE(103,30) SO4(I,II),NO3(I,II),CL(I,II),NH4(I,II),CA(I,II)
     1,MG(I,II),NA(I,II),K(I,II),H(I,II)
  60  CONTINUE
      RETURN
      END
```

```
C      THIS IS THE EQCON PROGRAM. IT IS PART OF THE OSAWD MODEL
C      FOR THE ADIRONDACK PARK OF NEW YORK STATE, WRITTEN BY
C      MARK SPRINGER AT OKLAHOMA STATE UNIVERSITY.
C
C      THIS PROGRAM CONVERTS IONIC CONCENTRATIONS FROM MG/L TO
C      UEQ/L AND CALLS SUBROUTINES TO CALCULATE THE OSAWD ESTIMATES
C      AND TABULATE THE ACTUAL AND ESTIMATED CONCENTRATIONS USING
C      BOOTH THE OSAWD AND ROGOWSKI MODELS , AND THE PERCENT DEVIATIONS
C      AND ESTIMATED ERRORS.
C      INPUT
C
C      140= THE FILE CONTAINING IONIC CONCENTRATIONS IN MG/L
C           FROM ONE OF THE FOUR RILWAS QUALITY MONITORING SITES
C
C      OUTPUT
C
C      150=THE IONIC CONCENTRATIONS IN UEQ/L FROM THE RILWAS
C          QUALITY MONITORING SITE SPECIFIED
C
C       SUBROUTINES
C
C       IONIC=CALCULATES THE IONIC CONCENTRATIONS USING THE OSAWD MODEL
C       CONC=TABULATES THE ACTUAL COMPOSTION, ESTIMATED COMPOSITON USING
C            THE OSAWD MODEL,THE PERCENT DEVIATION,AND THE ESTIMATED ERROR
C       ROGCK=TABULATES THE ACTUAL COMPOSITION,ESTIMATED COMPOSITION USING
C             THE ROGOWSKI MODEL,THE PERCENT DEVIATION,AND THE ESTIMATED
C             ERROR
C
       REAL SO4(24),NO3(24),CL(24),NH4(24),H(24)
       REAL CA(24),MG(24),NA(24),K(24),R(24),PH(24)
       REAL A(24),B(24),C(24),D(24),E(24),F(24),G(24)
       REAL X(24),Y(24)
       CHARACTER*8 AFILE
    1  WRITE (3,FMT='(24(/),16H ENTER FILE NAME)')
       READ (3,FMT='(A8)')AFILE
       IF(AFILE(1:3) .EQ. 'Q  ') GO TO 1000
       OPEN (UNIT=140,FILE=AFILE)
       OPEN (UNIT=150,FILE='EQUIV')
       WRITE (3,10)
   10  FORMAT (1X,'HOW MANY MONTHS DO YOU WISH TO CONVERT?')
       READ (3,11) MO
   11  FORMAT (I2)
       DO 20 I=1,MO
       READ (140,25) PH(I),R(I),SO4(I),NO3(I),CL(I),NH4(I),CA(I),
      1MG(I),NA(I),K(I)
       WRITE(3,25) PH(I),R(I),SO4(I),NO3(I),CL(I),NH4(I),CA(I),MG(I)
      1,NA(I),K(I)
   25  FORMAT (10(1X,F5.2))
       Y(I) = PH(I)/R(I)
       H(I) = 10**6*10**(-Y(I))
       A(I) = SO4(I)*62.4/R(I)
```

```
      B(I) = NO3(I)*71.4/R(I)
      C(I) = CL(I)*28.2/R(I)
      D(I) = NH4(I)*71.4/R(I)
      E(I) = CA(I)*49.9/R(I)
      F(I) = MG(I)*82.3/R(I)
      G(I) = NA(I)*43.5/R(I)
      X(I) = K(I)*25.6 /R(I)
   20 CONTINUE
      DO 40 I=1,MO
      WRITE (150,30) A(I),B(I),C(I),D(I),E(I),F(I),G(I),X(I),H(I)
   30 FORMAT(9(1X,F6.2))
   40 CONTINUE
      CLOSE 140
      CLOSE 150
      CALL IONIC
      CALL CONC
      CALL ROGCK
      GO TO 1
 1000 CONTINUE
      STOP
      END
```

```
C     THIS IS THE CONC SUBROUTINE OF THE EQCON PROGRAM. IT IS
C     PART OF THE OSAWD MODEL FOR THE ADIRONDACK PARK OF NEW
C     YORK STATE WRITTEN BY MARK SPRINGER OF OKLAHOMA STATE
C     UNIVERSITY.
C
C     THIS PROGRAM TABULATES THE ACTUAL COMPOSITION, THE ESTIMATED
C     ESTIMATED COMPOSITION USING THE OSAWD MODEL,THE PERCENT DEVIATION
C     AND THE ESTIMATED ERROR.
C
C     INPUTS
C
C     101=IONIC COMPOSITIONS RECORDED AT ONE OF THE FOUR RILWAS
C         MONITORING STATIONS IN UEQ/L
C     102=IONIC COMPOSITIONS ESTIMATED AT ONE OF THE FOUR RILWAS
C         MONITORING STATIONS USING THE OSAWD MODEL
C     104=ESTIMATED ERRORS
C
C     OUTPUTS
C
C     103=ACTUAL COMPOSITION, ESTIMATED COMPOSITION, PERCENT DEVIATION
C          , AND ESTIMATED ERROR
C     105=THE MAJOR IONS (SO4,NO3,H) AND THEIR RESPECTIVE ERRORS
C
      SUBROUTINE CONC
      REAL ESO4(24),ENO3(24),ECL(24),ENH4(24),ECA(24),EMG(24)
      REAL ENA(24),EK(24),EH(24),SO4(24),NO3(24),CL(24),NH4(24)
      REAL CA(24),MG(24),NA(24),K(24),H(24),E1(24),E2(24),E3(24)
      REAL E4(24),E5(24),E6(24),E7(24),E8(24),E9(24),EE1(24)
      REAL EE2(24),EE3(24),EE4(24),EE5(24),EE6(24),EE7(24)
      REAL EE8(24),EE9(24)
      OPEN (UNIT=101,FILE='EQUIV')
      OPEN (UNIT=102,FILE='FINAL')
      OPEN (UNIT=103,FILE='COMP1')
      OPEN (UNIT=104,FILE='EERR')
      OPEN (UNIT=105,FILE='OSU')
C     SET UP LOOP TO READ IN MONTHS DESIRED
      WRITE(3,*) 'HOW MANY MONTHS DO YOU WISH TO MODEL?'
      READ(3,*) MO
      DO 1 I=1,MO
C     READ IN ACTUAL, ESTIMATED IONIC CONCENTRATIONS AND PROBABLE ERROR
      READ(101,20) SO4(I),NO3(I),CL(I),NH4(I),CA(I),MG(I),NA(I),
     1K(I),H(I)
   20 FORMAT(9(1X,F6.2))
      READ(102,20) ESO4(I),ENO3(I),ECL(I),ENH4(I),ECA(I),EMG(I),
     1ENA(I),EK(I),EH(I)
      READ(104,20) EE1(I),EE2(I),EE3(I),EE4(I),EE5(I),EE6(I),EE7(I),
     1EE8(I),EE9(I)
C     CALCULATE PERCENT DEVIATION
      E1(I) = ((ESO4(I)-SO4(I))/SO4(I))*100.
      E2(I) = ((ENO3(I)-NO3(I))/NO3(I))*100.
      E3(I) = ((ECL(I)-CL(I))/CL(I))*100.
```

```
      E4(I) = ((ENH4(I)-NH4(I))/NH4(I))*100.
      E5(I) = ((ECA(I)-CA(I))/CA(I))*100.
      E6(I) = ((EMG(I)-MG(I))/MG(I))*100.
      E7(I) = ((ENA(I)-NA(I))/NA(I))*100.
      E8(I) = ((EK(I)-K(I))/K(I))*100.
      E9(I) = ((EH(I)-H(I))/H(I))*100.
C     ESTIMATE ERROR FROM PROBABLE ERROR
      EE1(I) = (EE1(I)/SO4(I))*100.
      EE2(I) = (EE2(I)/NO3(I))*100.
      EE3(I) = (EE3(I)/CL(I))*100.
      EE4(I) = (EE4(I)/NH4(I))*100.
      EE5(I) = (EE5(I)/CA(I))*100.
      EE6(I) = (EE6(I)/MG(I))*100.
      EE7(I) = (EE7(I)/NA(I))*100.
      EE8(I) = (EE8(I)/K(I))*100.
      EE9(I) = (EE9(I)/H(I))*100.
    1 CONTINUE
      DO 2 I=1,MO
      WRITE(103,20) SO4(I),NO3(I),CL(I),NH4(I),CA(I),MG(I),NA(I)
     1,K(I),H(I)
      WRITE(103,20) ESO4(I),ENO3(I),ECL(I),ENH4(I),ECA(I),EMG(I)
     1,ENA(I),EK(I),EH(I)
      WRITE(103,20) E1(I),E2(I),E3(I),E4(I),E5(I),E6(I),E7(I),
     1E8(I),E9(I)
      WRITE(103,20) EE1(I),EE2(I),EE3(I),EE4(I),EE5(I),EE6(I),
     1EE7(I),EE8(I),EE9(I)
      WRITE(105,60) ESO4(I),ENO3(I),EH(I),EE1(I),EE2(I),EE9(I)
   60 FORMAT(6(1X,F6.2))
      WRITE(103,50)
   50 FORMAT(//)
    2 CONTINUE
      CLOSE 101
      CLOSE 102
      CLOSE 103
      CLOSE 104
      RETURN
      END
```

```
C      THIS IS THE ROGCK SUBROUTINE OF THE EQCON PROGRAM. IT IS PART OF
C      THE OSAWD MODEL FOR THE ADIRONDACK PARK OF NEW YORK STATE WRITTEN BY
C      MARK SPRINGER AT OKLAHOMA STATE UNIVERSITY.
C
C      THIS PROGRAM TABULATES THE ACTUAL COMPOSITION,THE ESTIMATED COMPOSITION
C      USING ROGOWSKI'S METHOD, THE PERCENT DEVIATION, AND THE ESTIMATED ERROR
C
C      INPUTS
C
C      101=IONIC COMPOSITIONS RECORDED AT ONE OF THE FOUR RILWAS
C          QUALITY MONITORING STATIONS IN UEQ/L.
C      102=IONIC COMPOSITIONS RECORDED AT ITHACA NEW YORK
C      104=IONIC COMPOSITIONS RECORDED AT WHITEFACE MTN. NEW YORK
C      105=ESTIMATED ERRORS
C
C      OUTPUTS
C
C      103=ACTUAL COMPSITION, ESTIMATED COMPOSITION, PERCENT DEVIATION,
C          AND ESTIMATED ERROR
C      106=THE MAJOR IONS (SO4,NO3,H)AND THEIR RESPECTIVE ERRORS
C
       SUBROUTINE ROGCK
       REAL ES04(24),ENO3(24),ECL(24),ENH4(24),ECA(24),EMG(24)
       REAL ENA(24),EK(24),EH(24),SO4(24),NO3(24),CL(24),NH4(24)
       REAL CA(24),MG(24),NA(24),K(24),H(24),E1(24),E2(24),E3(24)
       REAL E4(24),E5(24),E6(24),E7(24),E8(24),E9(24),ISO4(24)
       REAL INO3(24),ICL(24),INH4(24),ICA(24),IMG(24),INA(24),IK(24)
       REAL IH(24),WSO4(24),WNO3(24),WCL(24),WNH4(24),WCA(24),WMG(24)
       REAL WNA(24),WK(24),WH(24),EE1(24),EE2(24),EE3(24),EE4(24)
       REAL EE5(24),EE6(24),EE7(24),EE8(24),EE9(24)
       OPEN (UNIT=101,FILE='EQUIV')
       OPEN (UNIT=102,FILE='ITH')
       OPEN (UNIT=103,FILE='COMP2')
       OPEN (UNIT=104,FILE='WHI')
       OPEN (UNIT=105,FILE='EERR')
       OPEN (UNIT=106,FILE='ROGO')
C      SET UP A LOOP TO READ THE MONTHS DESIRED
       WRITE(3,*) 'HOW MANY MONTHS DO YOU WISH TO MODEL?'
       READ(3,*) MO
       DO 1 I=1,MO
C      READ IN ACTUAL,ESTIMATED IONIC CONCENTRATIONS AND PROBABLE ERROR
       READ(101,20) SO4(I),NO3(I),CL(I),NH4(I),CA(I),MG(I),NA(I),
      1K(I),H(I)
   20  FORMAT(9(1X,F6.2))
       READ(102,20) ISO4(I),INO3(I),ICL(I),INH4(I),ICA(I),IMG(I),
      1INA(I),IK(I),IH(I)
       READ(104,20) WSO4(I),WNO3(I),WCL(I),WNH4(I),WCA(I),WMG(I),
      1WNA(I),WK(I),WH(I)
       READ(105,20) EE1(I),EE2(I),EE3(I),EE4(I),EE5(I),EE6(I),
      1EE7(I),EE8(I),EE9(I)
C      ESTIMATE THE IONIC CONCENTRATIONS USING ROGOWSKI'S METHOD
```

```
      ES04(I) = (IS04(I)+WS04(I))/2.
      ENO3(I) = (INO3(I)+WNO3(I))/2.
      ECL(I) = (ICL(I)+WCL(I))/2.
      ENH4(I) = (INH4(I)+WNH4(I))/2.
      ECA(I) = (ICA(I)+WCA(I))/2.
      EMG(I) = (IMG(I)+WMG(I))/2.
      ENA(I) = (INA(I)+WNA(I))/2.
      EK(I) = (IK(I)+WK(I))/2.
      EH(I) = (IH(I)+WH(I))/2.
      E1(I) = ((ES04(I)-S04(I))/S04(I))*100.
      E2(I) = ((ENO3(I)-NO3(I))/NO3(I))*100.
      E3(I) = ((ECL(I)-CL(I))/CL(I))*100.
      E4(I) = ((ENH4(I)-NH4(I))/NH4(I))*100.
      E5(I) = ((ECA(I)-CA(I))/CA(I))*100.
      E6(I) = ((EMG(I)-MG(I))/MG(I))*100.
      E7(I) = ((ENA(I)-NA(I))/NA(I))*100.
      E8(I) = ((EK(I)-K(I))/K(I))*100.
      E9(I) = ((EH(I)-H(I))/H(I))*100.
C     ESTIMATE PERCENT ERROR FROM PROBABLE ERROR
      EE1(I) = (EE1(I)/S04(I))*100.
      EE2(I) = (EE2(I)/NO3(I))*100.
      EE3(I) = (EE3(I)/CL(I))*100.
      EE4(I) = (EE4(I)/NH4(I))*100.
      EE5(I) = (EE5(I)/CA(I))*100.
      EE6(I) = (EE6(I)/MG(I))*100.
      EE7(I) = (EE7(I)/NA(I))*100.
      EE8(I) = (EE8(I)/K(I))*100.
      EE9(I) = (EE9(I)/H(I))*100.
    1 CONTINUE
      DO 2 I=1,MO
      WRITE(103,20) S04(I),NO3(I),CL(I),NH4(I),CA(I),MG(I),NA(I)
     1,K(I),H(I)
      WRITE(103,20) ES04(I),ENO3(I),ECL(I),ENH4(I),ECA(I),EMG(I)
     1,ENA(I),EK(I),EH(I)
      WRITE(103,20) E1(I),E2(I),E3(I),E4(I),E5(I),E6(I),E7(I),
     1E8(I),E9(I)
      WRITE(103,20) EE1(I),EE2(I),EE3(I),
     1EE4(I),EE5(I),EE6(I),EE7(I),EE8(I),EE9(I)
      WRITE(103,50)
      WRITE(106,60) ES04(I),ENO3(I),EH(I),EE1(I),EE2(I),EE9(I)
   60 FORMAT(6(1X,F6.2))
   50 FORMAT(//)
    2 CONTINUE
      CLOSE 101
      CLOSE 102
      CLOSE 103
      CLOSE 104
      CLOSE 105
      RETURN
      END
```

```
C       THIS IS THE ENDER PROGRAM. IT IS PART OF THE OSAWD MODEL
C       FOR THE ADIRONDACK PARK OF NEW YORK STATE WRITTEN BY MARK
C       SPRINGER AT OKLAHOMA STATE UNIVERSITY.
C
C       THIS PROGRAM CALCULATES THE ESTIMATED ERRORS IN IONIC COMPOSITION
C
C       INPUTS
C
C       101=THE PERCENTAGE OF RAINFALL IN THE LAST WEEK OF THE MONTH
C           CALCULATED BY HAND
C
C       OUTPUT
C
C       102=ESTIMATED ERROR
C
        REAL ES04(24),EN03(24),ECL(24),ENH4(24)
        REAL ENA(24),EK(24),ECA(24),EMG(24),EH(24)
        REAL EE1(24),EE2(24),EE3(24),EE4(24),EE5(24)
        REAL E(24),EE6(24),EE7(24),EE8(24),EE9(24)
        OPEN(UNIT=101,FILE='MOERR')
        OPEN(UNIT=102,FILE='EERR')
        SS04 = 23.87
        SN03 = 27.62
        SCL = 3.07
        SNH4 = 26.40
        SNA = 3.54
        SK = 7.44
        SCA = 5.87
        SMG = 1.47
        SH = 38.60
        DO 10 I=1,24
        READ(101,15) E(I)
 15     FORMAT(1X,F4.2)
C       ENDING ERRORS ARE ESTIMATED USING THE FRACTION OF RAIN IN THE
C       LAST WEEK AND 66% OF THE ESTIMATED RAINFALL VARIANCE.
        ES04(I) = E(I)*0.666*SS04
        EN03(I) = E(I)*0.666*SN03
        ECL(I) = E(I)*0.666*SCL
        ENH4(I) = E(I)*0.666*SNH4
        ECA(I) = E(I)*0.666*SCA
        EMG(I) = E(I)*0.666*SMG
        ENA(I) = E(I)*0.666*SNA
        EK(I) = E(I)*0.666*SK
        EH(I) = E(I)*0.666*SH
C       TOTAL ESTIMATED ERROR IS CALCULATED FROM THE ENDING ERROR,
C       THE ERROR IN MEASUREMENT AND THE AREAL ERROR.
        EE1(I) = ES04(I)+13.01+0.01
        EE2(I) = EN03(I)+7.24+0.02
        EE3(I) = ECL(I)+2.00
        EE4(I) = ENH4(I)+4.32+0.07
        EE5(I) = ECA(I)+2.63+0.12
```

```
      EE6(I) = EMG(I)+ 0.88+0.15
      EE7(I) = ENA(I)+2.05
      EE8(I) = EK(I)+0.69+0.02
      EE9(I) = EH(I)+15.99
      WRITE(102,50) EE1(I),EE2(I),EE3(I),EE4(I)
     1,EE5(I),EE6(I),EE7(I),EE8(I),EE9(I)
 50   FORMAT(9(1X,F6.2))
 10   CONTINUE
      STOP
      END
```

```
C       THIS IS THE VIRTLS (VIRTUAL SOURCE FINDER) PROGRAM. IT
C       IS PART OF THE OSAWD MODEL FOR THE ADIRONDACK PARK OF
C       OF NEW YORK STATE,WRITTEN BY MARK SPRINGER AT OKLAHOMA
C       STATE UNIVERSITY.
C
C       INPUTS
C
C       110=CONCENTRATION OF SULFATE IONS RECORDED AT ITHACA NEW YORK
C       120=CONCENTRATION OF SULFATE IONS RECORDED AT WHITEFACE MTN. NEW YORK
C
C       OUTPUT
C
C       130=DISTANCE OF VIRTUAL SOURCE FROM ITHACA NEW YORK
C
C       THE VIRTUAL SOURCE IS CALCULATED FOR EACH MONTH FOR WHICH
C       RILWAS DATA COLLECTED USING THE MAP3S DATA FROM ITHACA AND
C       WHITEFACE MTN. NEW YORK.
C
        REAL ISO4(24),WSO4(24),RATIO(24)
        REAL ADIFF
        INTEGER FLAGP,FLAGN
        OPEN (UNIT=110,FILE='ITH')
        OPEN (UNIT=120,FILE='WHI')
        OPEN (UNIT=130,FILE='SOURCE')
C       READ IN THE NUMBER OF MONTHS DESIRED AND BEGIN
C       A LOOP TO CALCULATE VIRTUAL SOURCE DISTANCES.
        WRITE(3,*) 'HOW MANY MONTHS DO TOU WISH TO MODEL'?
        READ (3,*) MO
        DO 5 I=1,MO
        READ(110,15) ISO4(I)
        READ(120,15) WSO4(I)
     15 FORMAT(1X,F6.2)
C       INITIALIZE FLAGS AND INTERVAL FOR USE IN
C       INTERVAL HALVING TECHNIQUE.
        FLAGP = -1
        FLAGN = -1
        XINC = 50.
        X = 100.
C       CALCULATE DIFFUSION/DISPERSION COEFFICIENTS FOR ITHACA
C       USING WARK AND WARNER'S METHOD FOR CLASS 'D' STABILITY.
     10 A = 68.*X**0.894
        B = (44.5*X**0.516)-13.0
C       REPEAT THE DIFFUSION/DISPERSION CALCULATIONS FOR
C       WHITEFACE MTN. (357KM FROM ITHACA).
        DX = X + 357.
        C = 68.*DX**0.894
        D = (44.5*DX**C.516)-13.0
C       BEGIN INTERVAL HALVING TECHNIQUE.
        DIFF = A*B - RATIO(I)*C*D
C       WRITE(3,*) 'DIFF=',DIFF
        ADIFF = ABS(DIFF)
```

```
          IF(ADIFF .LE. 0.1) GO TO 100
          IF(DIFF .GT. 0.) THEN
            FLAGP = 1
            IF(FLAGN .NE.- 1) XINC = XINC/2.
            X = X - XINC
          ELSE
            FLAGN = 1
            IF(FLAGP .NE. -1) XINC = XINC/2.
            X = X + XINC
          ENDIF
          GO TO 10
      100 CONTINUE
          DVIR(I) = X
          WRITE(130,40) DVIR(I)
       40 FORMAT(1X,F6.0)
        5 CONTINUE
          STOP
          END
```

APPENDIX B

RAINFALL QUANTITY MAPS

Rainfall (cm) for July 1982

Figure 14

Rainfall (cm) for August 1982

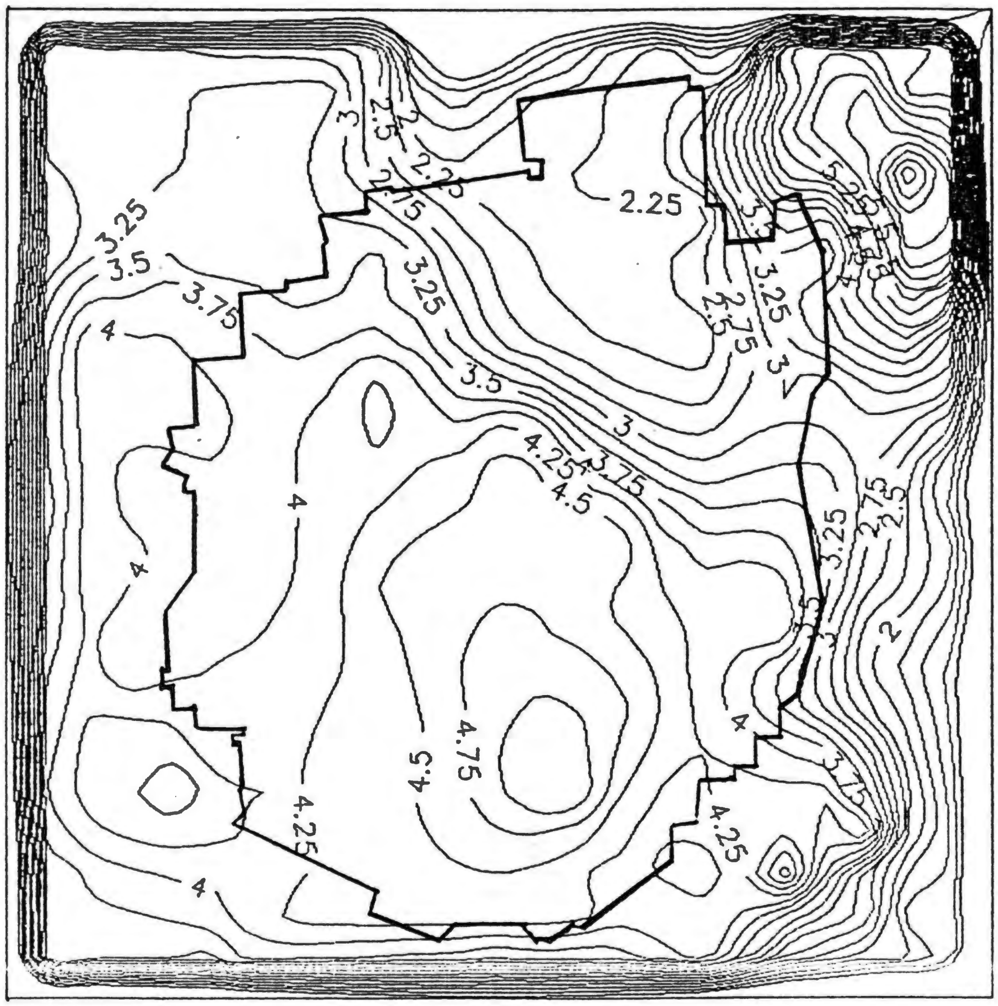

Figure 15

Rainfall (cm) for September 1982

Figure 16

Rainfall (cm) for October 1982

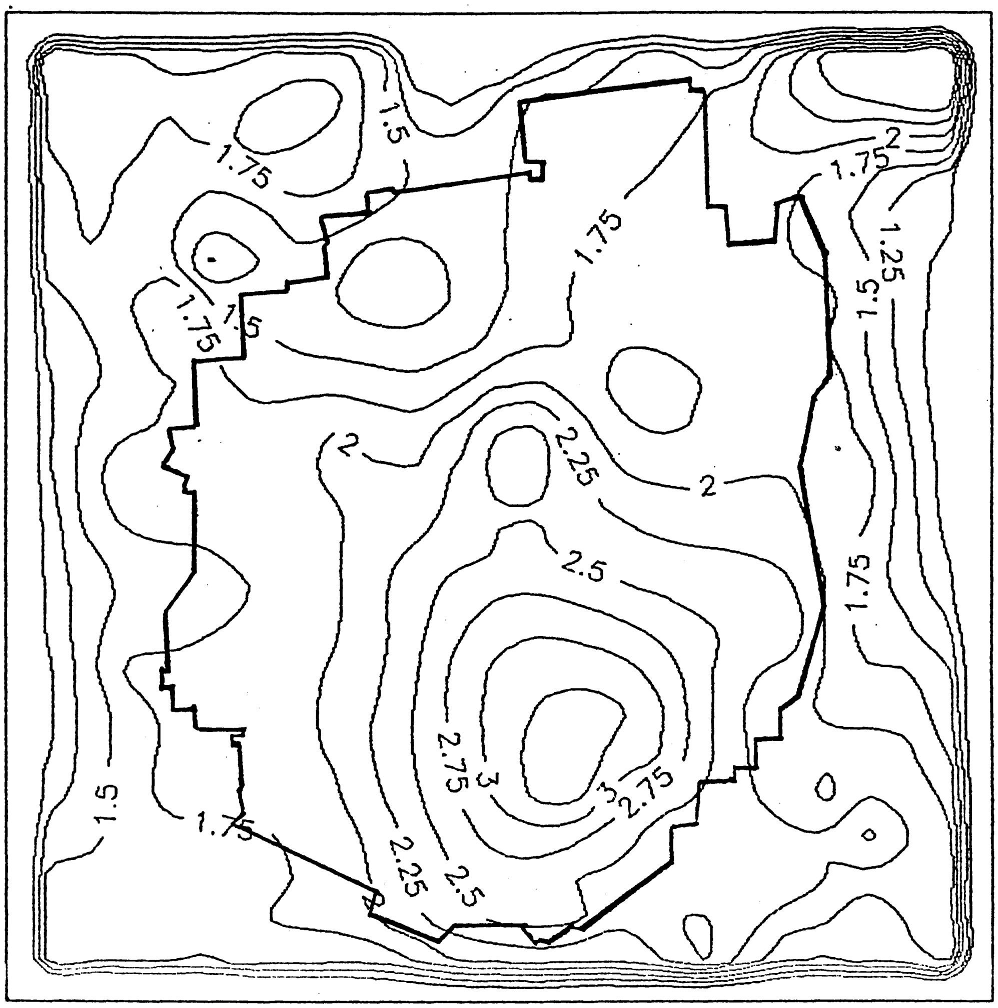

Figure 17

Rainfall (cm) for November 1982

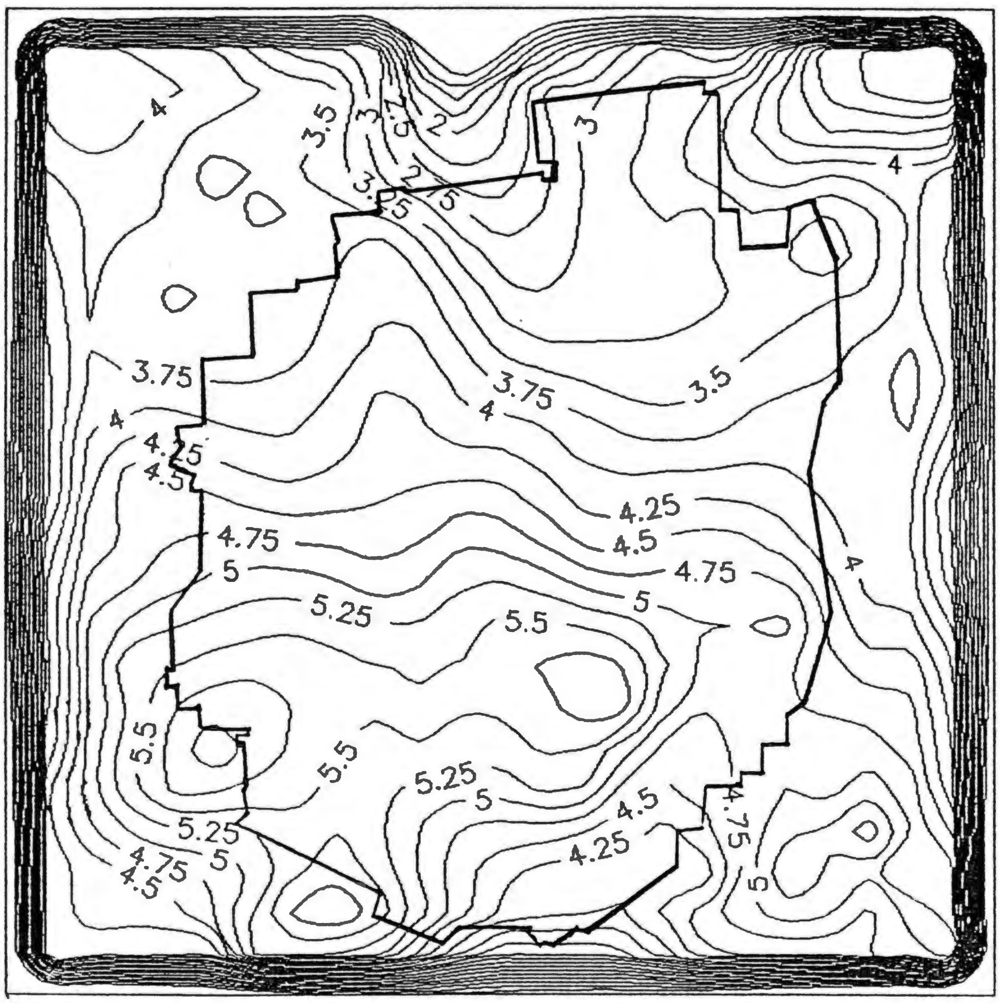

Figure 18

Rainfall (cm) for December 1982

Figure 19

Rainfall (cm) for January 1983

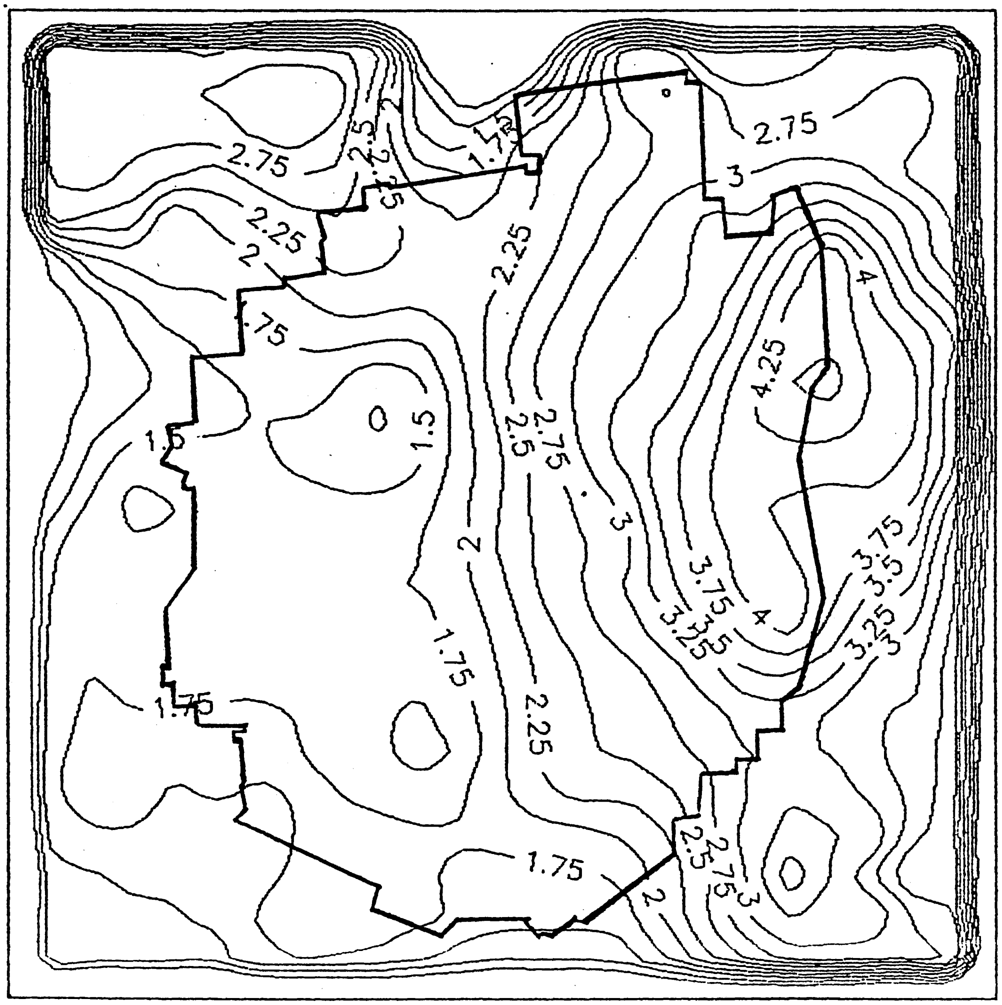

Figure 20

Rainfall (cm) for February 1983

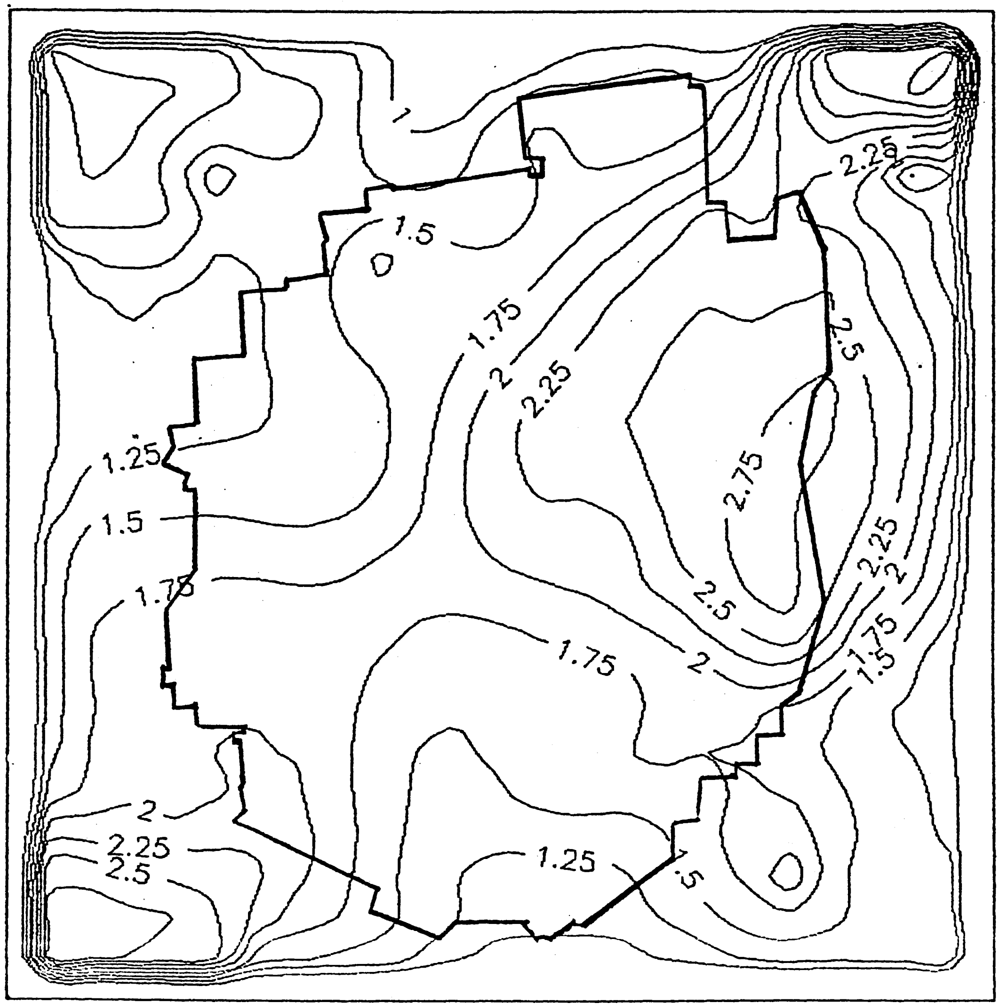

Figure 21

Rainfall (cm) for March 1983

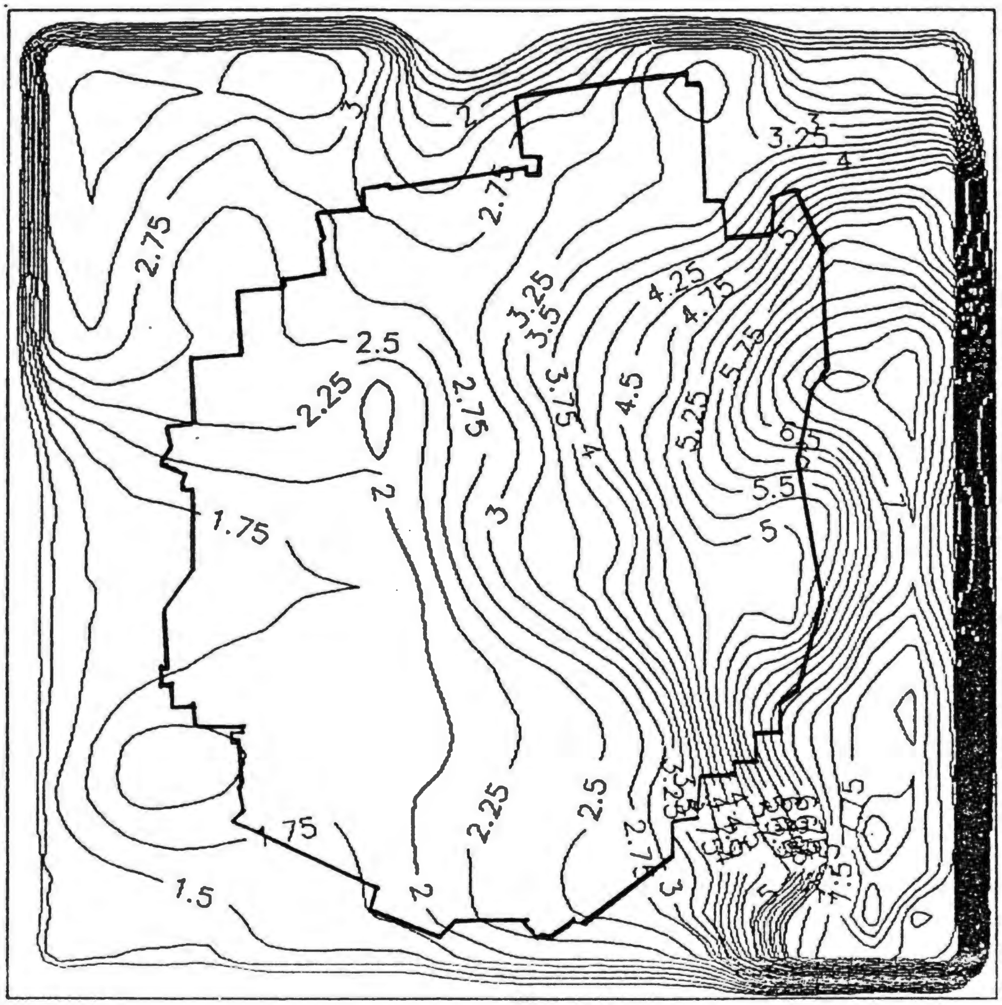

Figure 22

Rainfall (cm) for April 1983

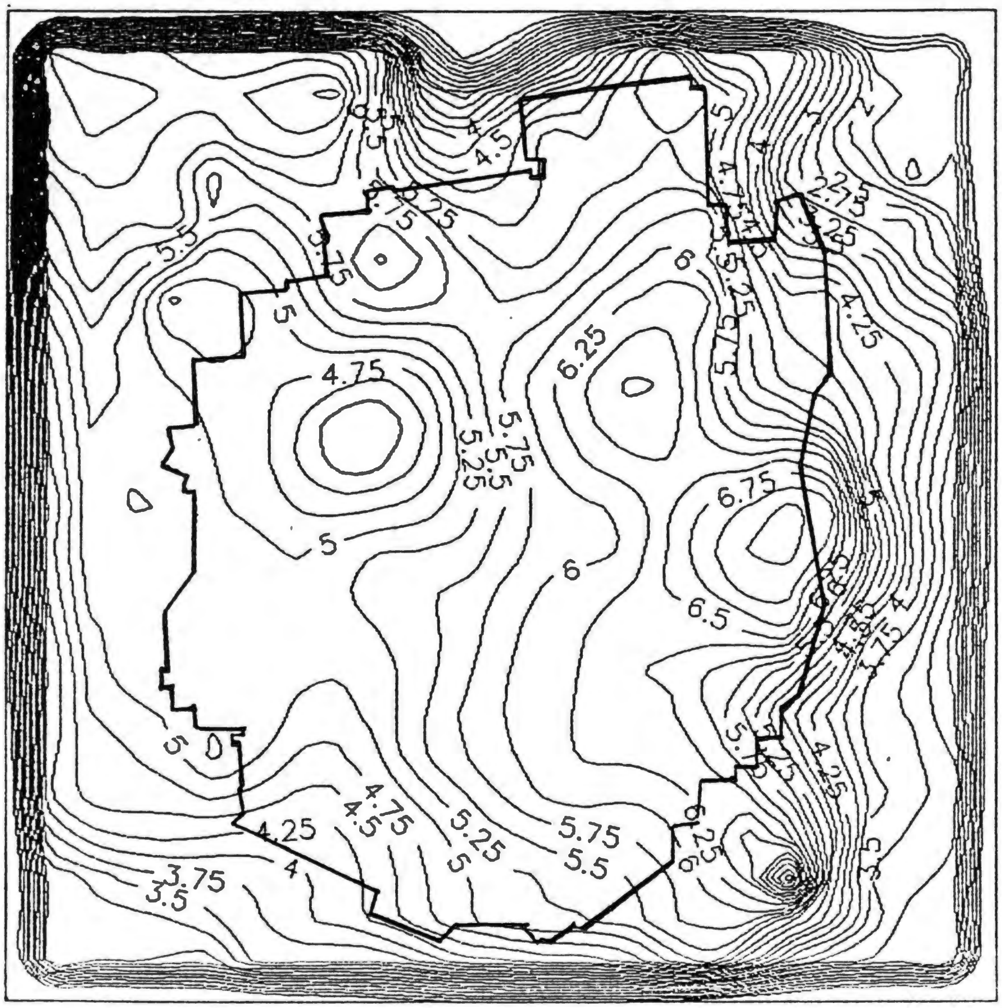

Figure 23

Rainfall (cm) for May 1983

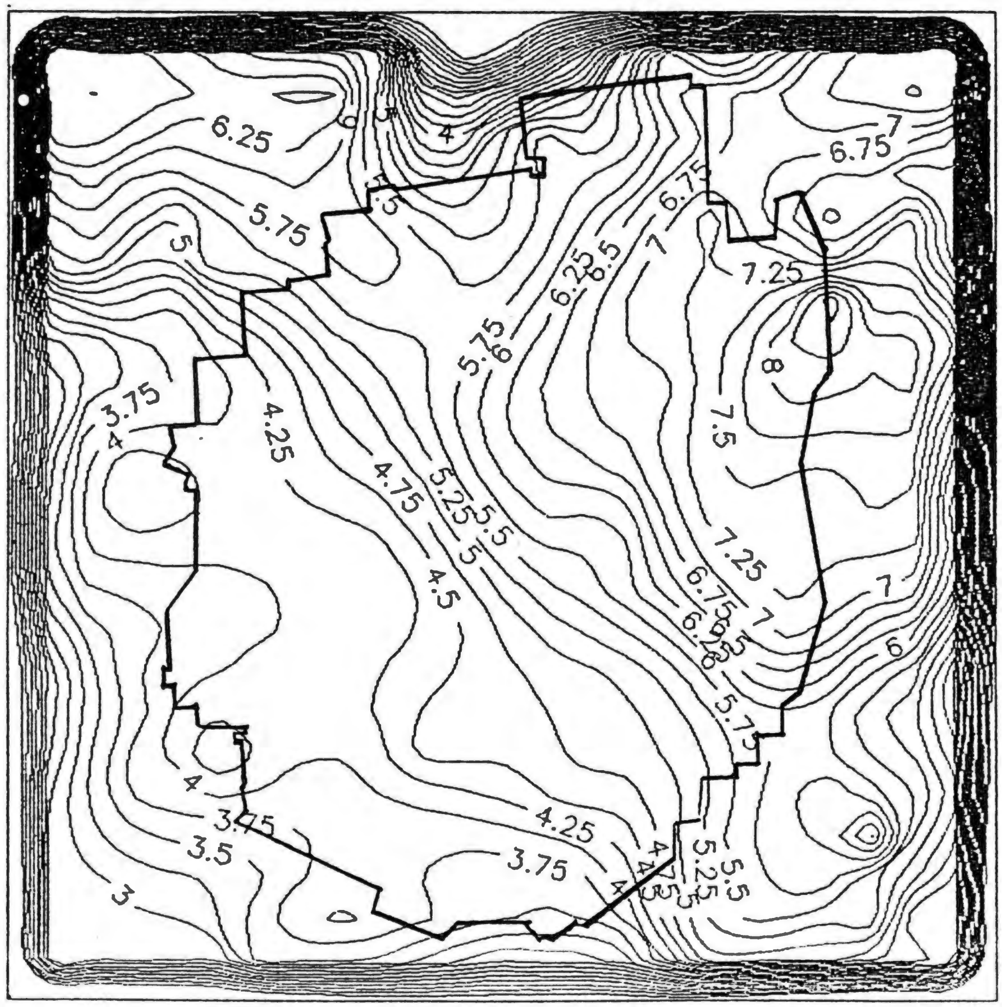

Figure 24

Rainfall (cm) for June 1983

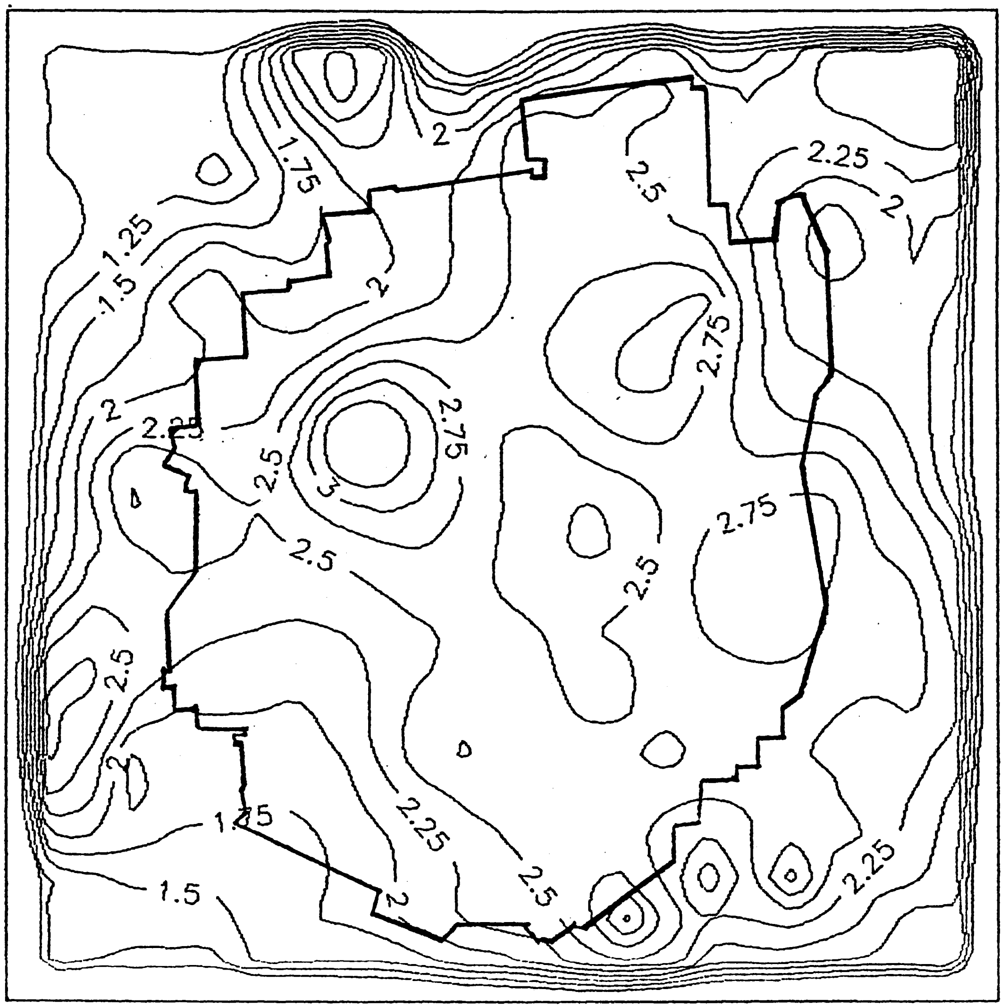

Figure 25

Rainfall (cm) for July 1983

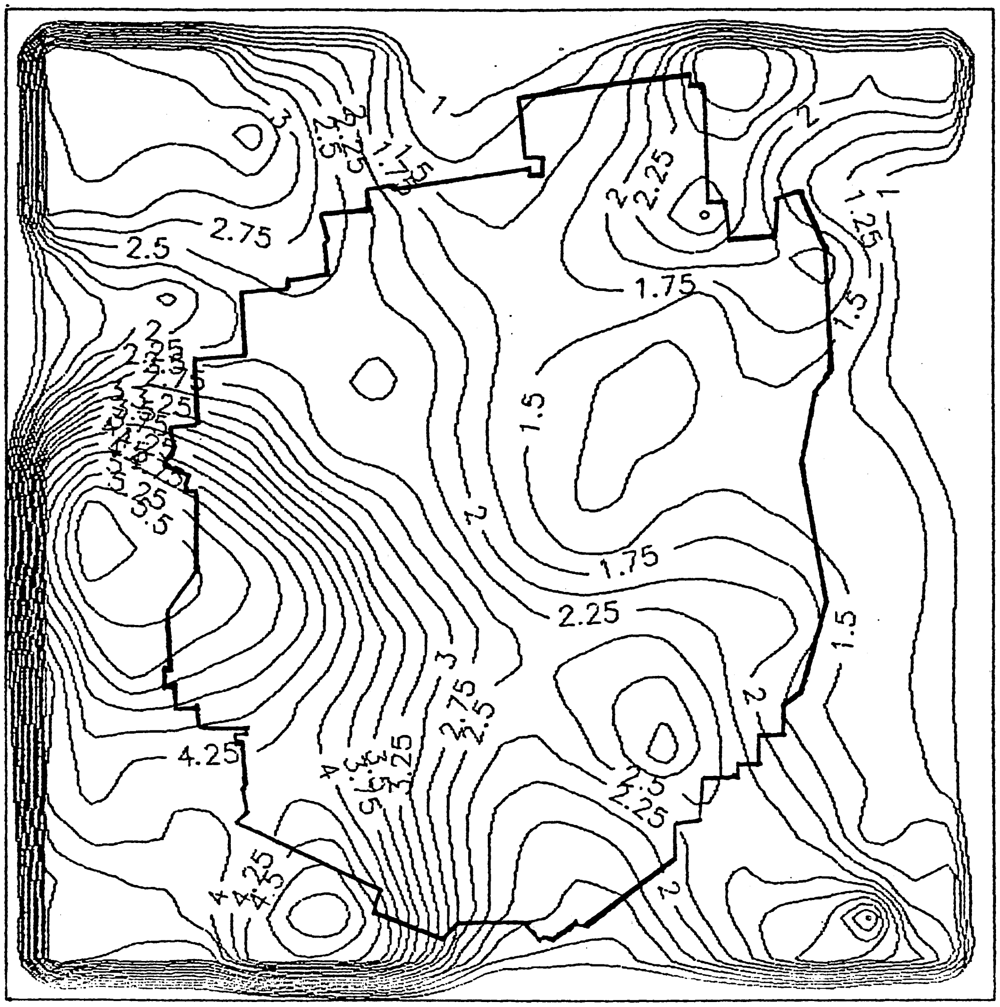

Figure 26

Rainfall (cm) for August 1983

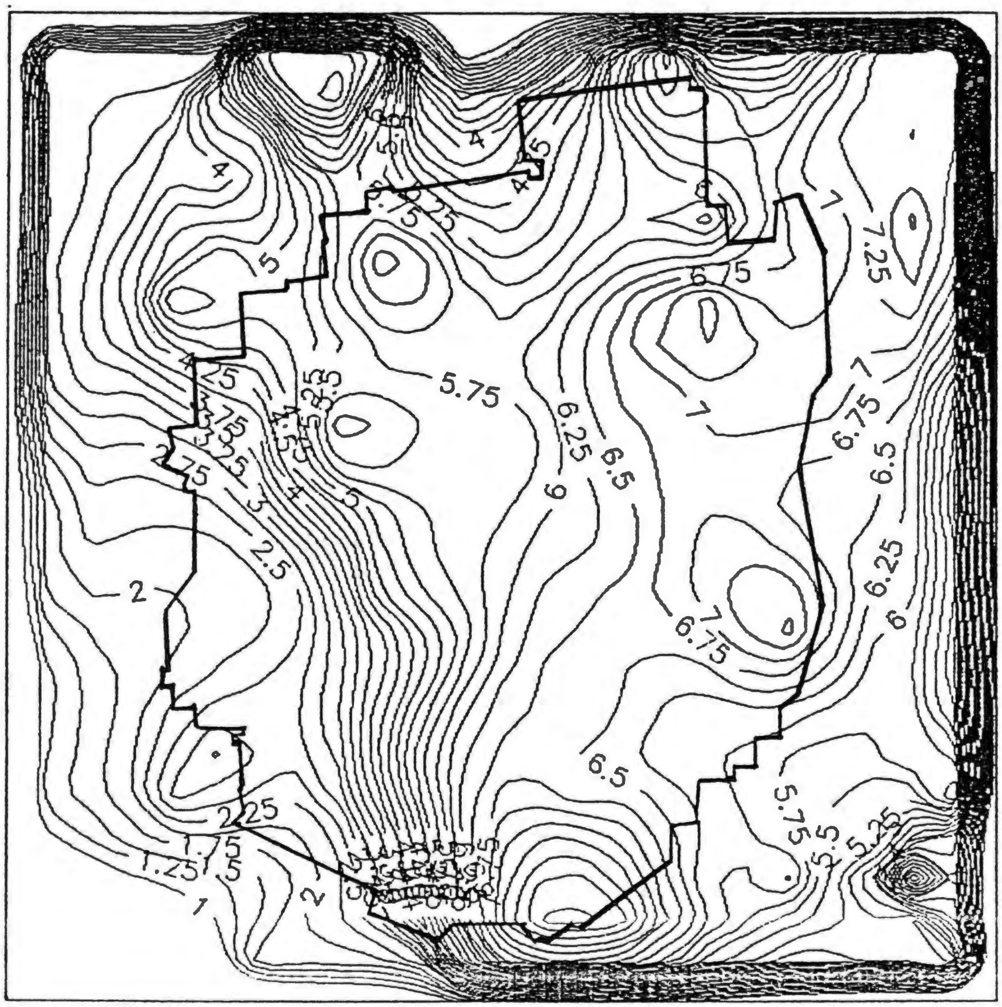

Figure 27

Rainfall (cm) for September 1983

Figure 28

Rainfall (cm) for October 1983

Figure 29

Rainfall (cm) for November 1983

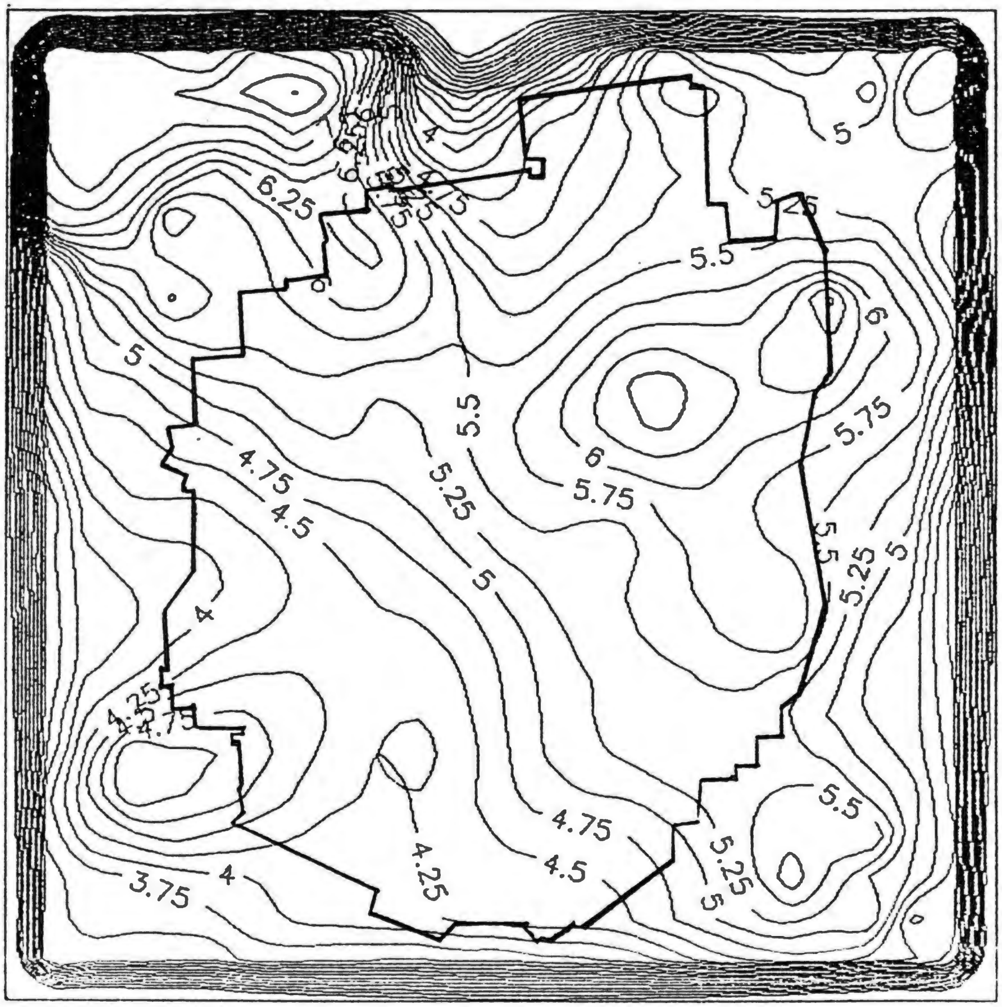

Figure 30

Rainfall (cm) for December 1983

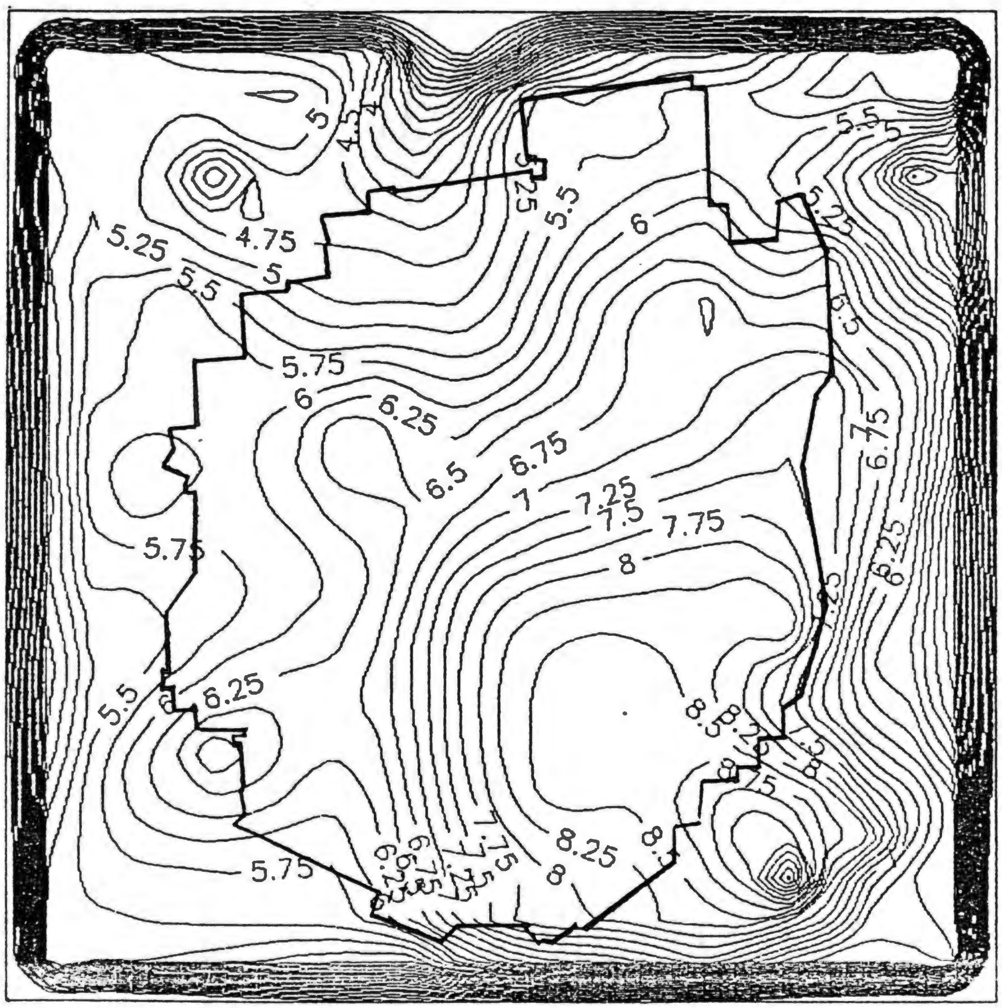

Figure 31

Rainfall (cm) for January 1984

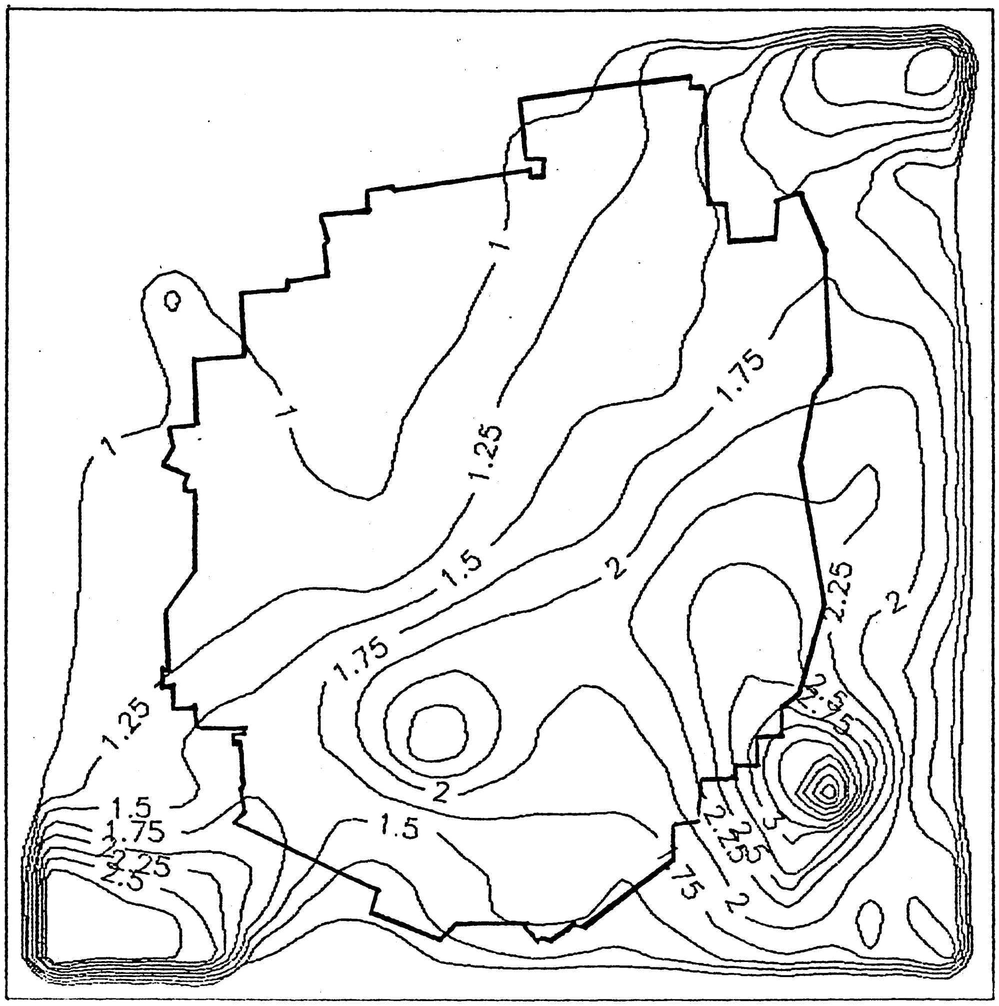

Figure 32

Rainfall (cm) for February 1984

Figure 33

Rainfall (cm) for March 1984

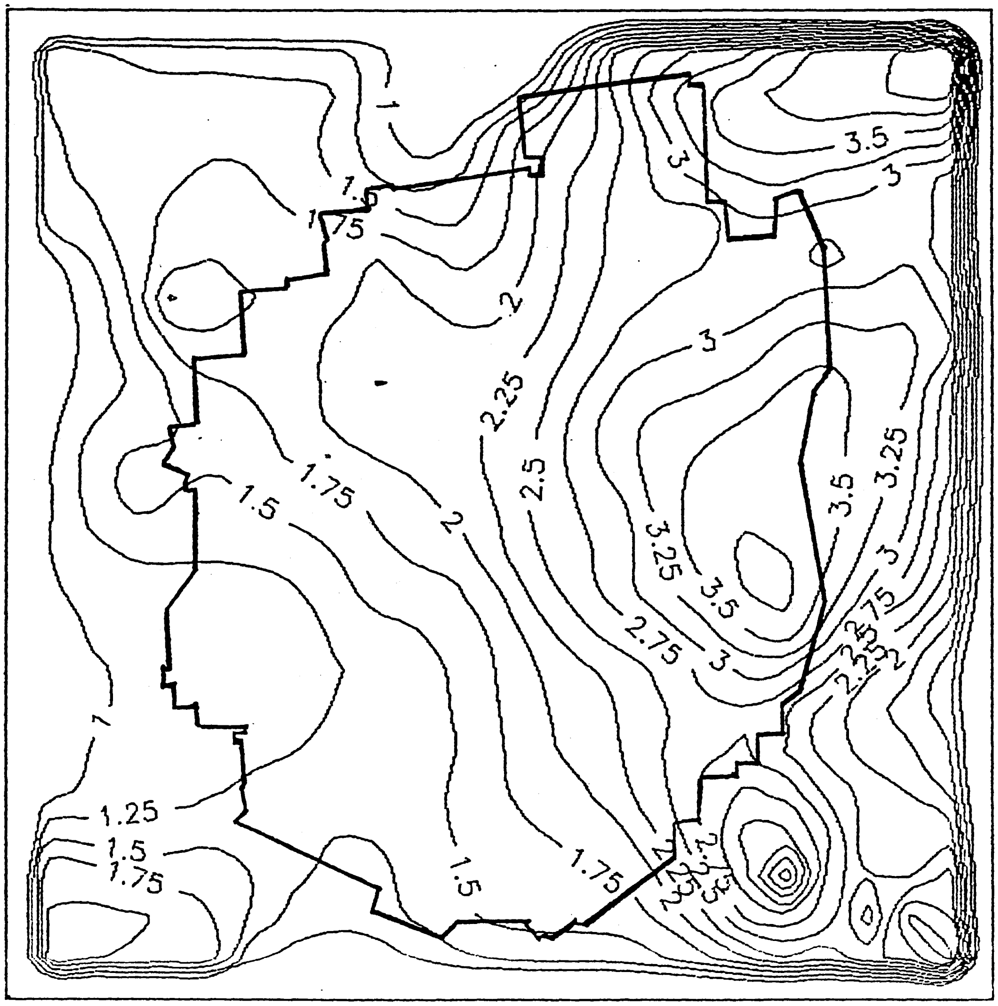

Figure 34

Rainfall (cm) for April 1984

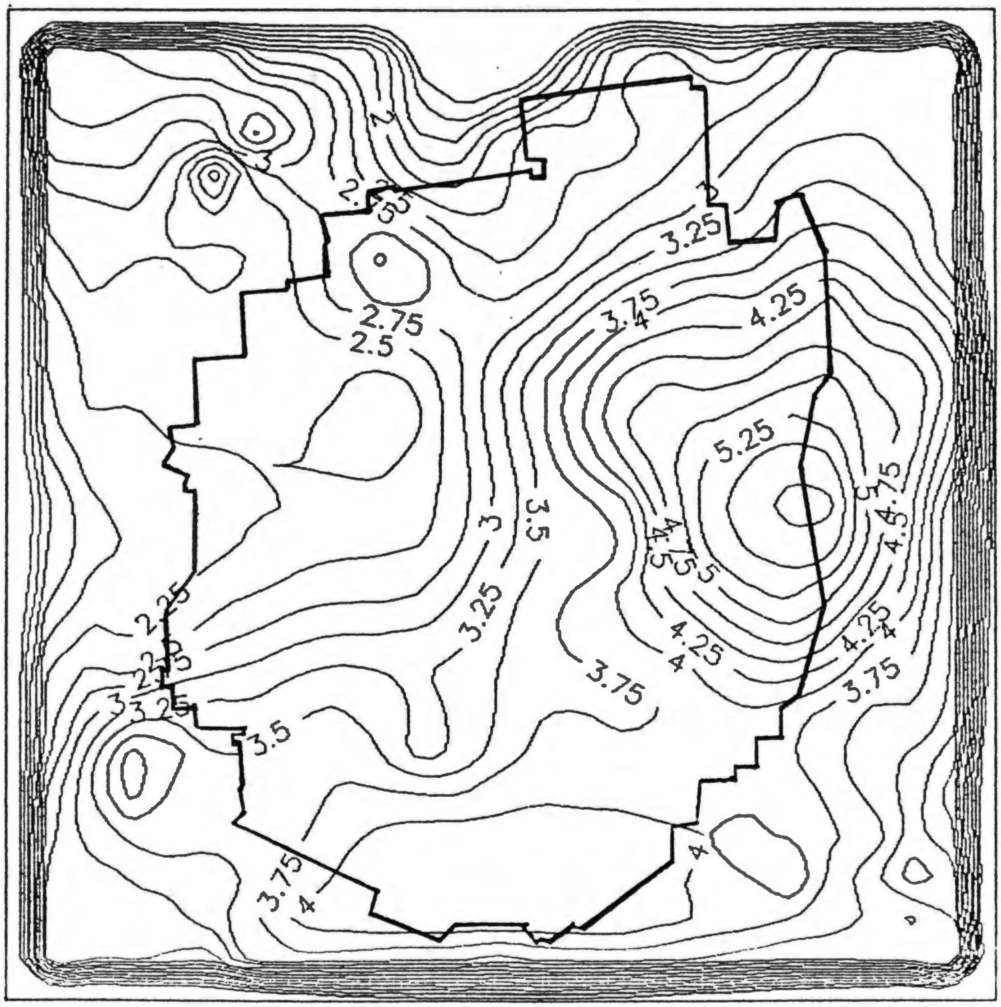

Figure 35

Rainfall (cm) for May 1984

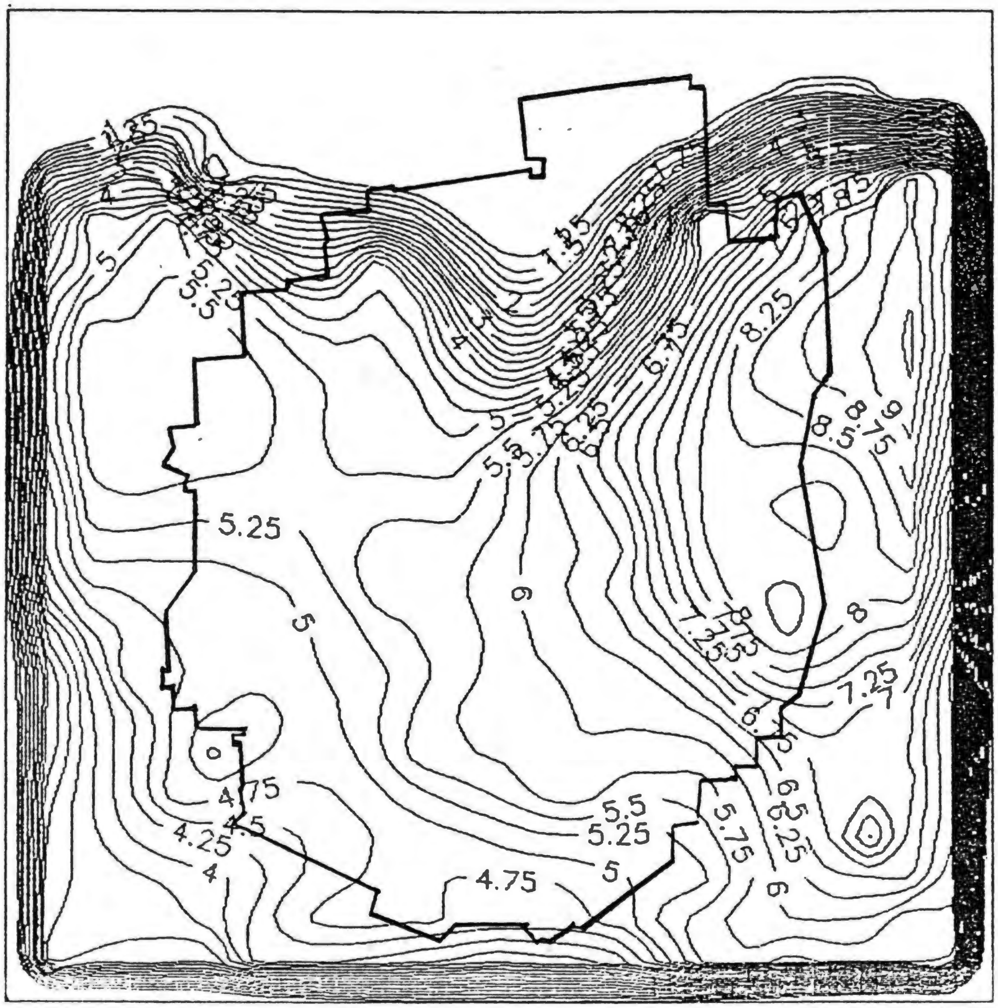

Figure 36

Rainfall (cm) for June 1984

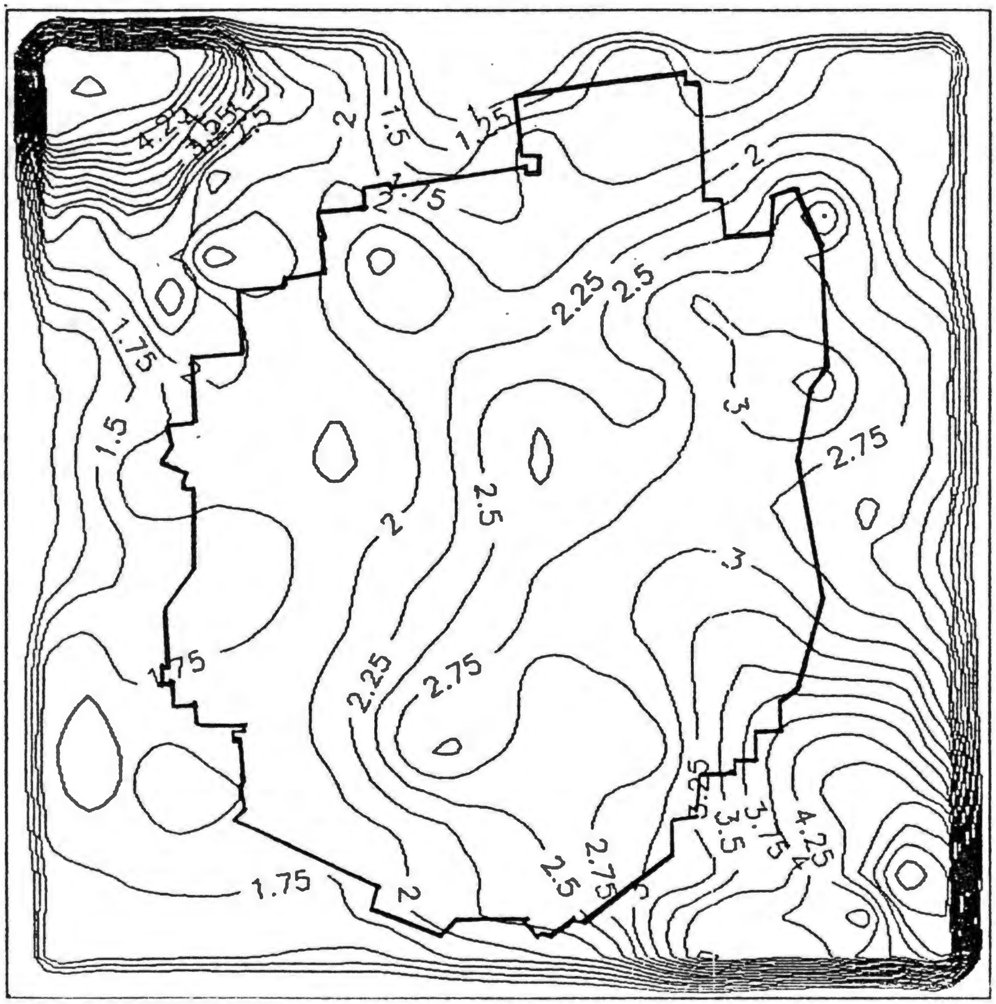

Figure 37

SURFER^{TM} automatically assigns contour lines in the "GRID" procedure. the "SEARCH" option searchs the 10 nearest points, looking for data points. If no points are found within the search area, the grid data value will be blanked,and a contour line will not be drawn. The search will continue at the next non blanked search area, and then repeat the process. The seach radius is based on the diagonal of the data limits. If there are less than 10 data points within the search radius, then it will search all of the data points within the radius. If there are no data points within the search radius,the grid data value will be blanked.

Two other search methods exist as options, the Quadrant,and Octant methods. These methods use 4 and 8 nearest neighbors respectively as their search areas. These two methods and their effects on the contouring are discussed in the SURFER^{TM} User's Manual (40).

VITA

Mark Lincoln Springer

Candidate for the degree of

Master of Science

Thesis: A STATISTICAL ANALYSIS OF WET LOADING MODELS FOR THE ADIRONDACK PARK

Major Field: Chemical Engineering

Biographical:

Personal data: Born in LaCrosse, Wisconsin, August 4, 1958, the son of Charles and Jeanine Springer.

Education: Graduated from Fayetteville High School, Fayetteville, Arkansas, May, 1976; received Bachelor of Science in Chemical Engineering from the University of Arkansas in August, 1981; completed requirements for the Master of Science degree at Oklahoma State University in July, 1987.

Professional experience: Process Engineer, Monsanto Agricultural Products Company, Muscatine, Iowa, July, 1981 to April, 1984; Teaching Assistant, School of Chemical Engineering, Oklahoma State University, January, 1985 to May, 1987; member of Omega Chi Epsilon, AICHE, and OSPE (NSPE).